US007012178B2

(12) **United States Patent**
Muramatsu

(10) **Patent No.: US 7,012,178 B2**
(45) **Date of Patent: Mar. 14, 2006**

(54) **COMPACT MUSICAL INSTRUMENT EQUIPPED WITH AUTOMATIC PLAYER**

(75) Inventor: **Shigeru Muramatsu**, Shizuoka (JP)

(73) Assignee: **Yamaha Corporation**, (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 248 days.

(21) Appl. No.: **10/361,614**

(22) Filed: **Feb. 11, 2003**

(65) **Prior Publication Data**

US 2003/0150316 A1 Aug. 14, 2003

(30) **Foreign Application Priority Data**

Feb. 13, 2002	(JP)	....	2002-035403
Mar. 20, 2002	(JP)	....	2002-079132
Mar. 20, 2002	(JP)	....	2002-079133
Mar. 20, 2002	(JP)	....	2002-079134
Mar. 20, 2002	(JP)	....	2002-079151

(51) **Int. Cl.**
G10F 1/06 (2006.01)

(52) **U.S. Cl.** **84/97**; 84/100

(58) **Field of Classification Search** 84/100, 84/94.2, 94.1, 95.1, 95.2, 96–99
See application file for complete search history.

(56) **References Cited**

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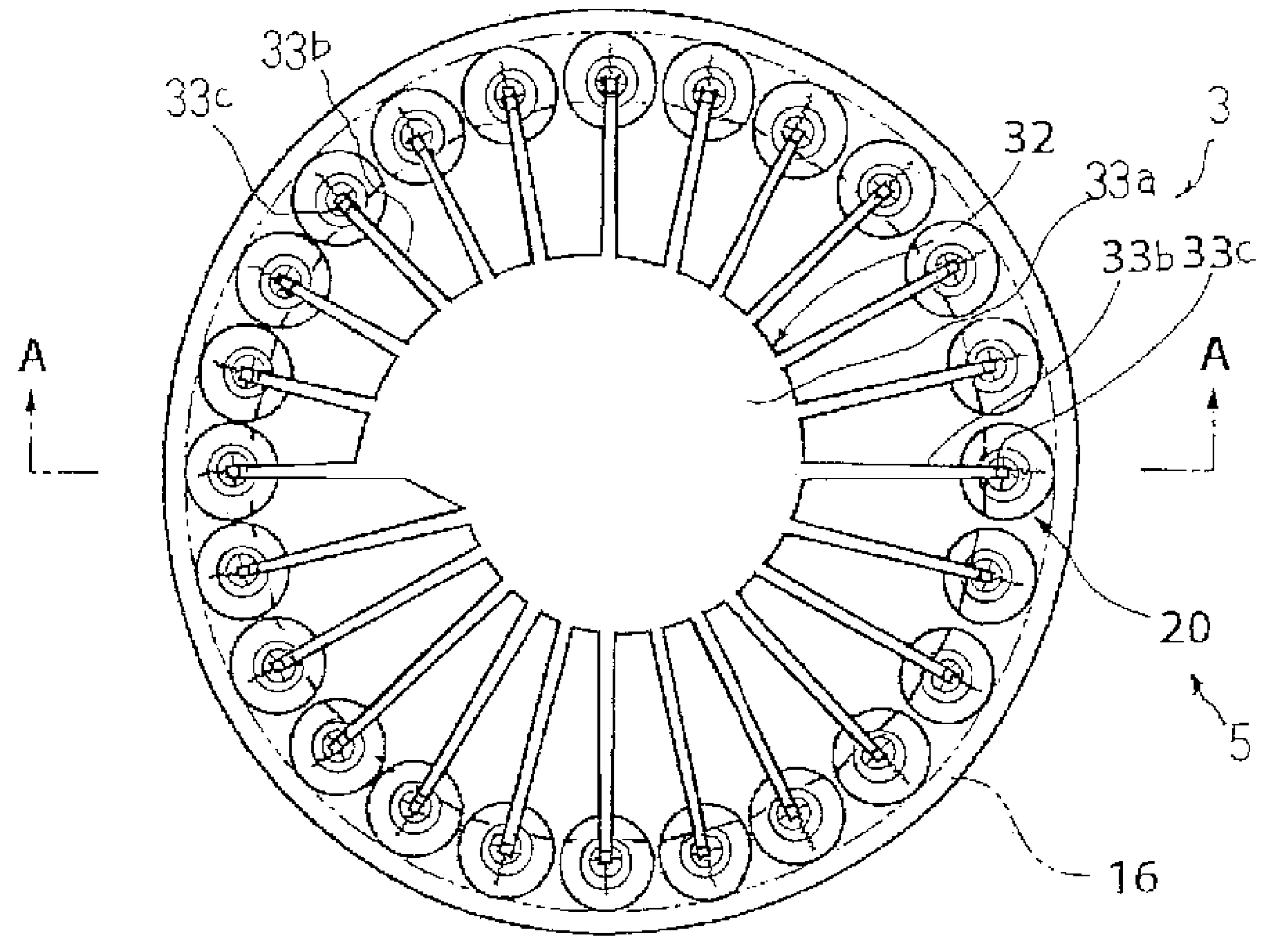
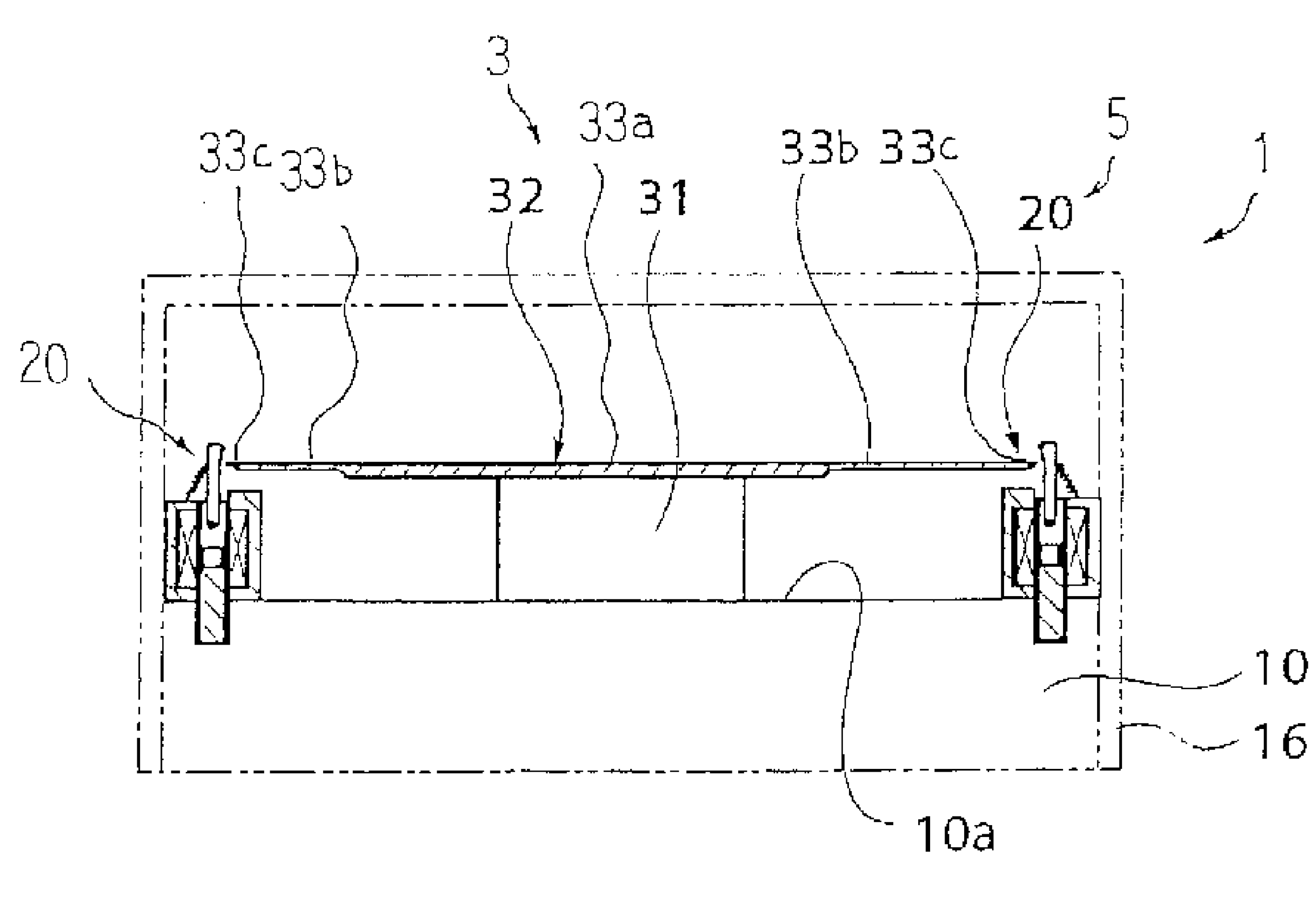
Primary Examiner—Kimberly Lockett
(74) *Attorney, Agent, or Firm*—Dickstein, Shapiro, Morin & Oshinsky, L.L.P.

(57) **ABSTRACT**

A music box includes a daisy reed wheel having reeds radially projecting from a hub for generating tones and solenoid-operated player's fingers arranged around the daisy reed wheel; the tips of the reeds are widely spaced from one another by virtue of the radial arrangement so that large-sized solenoid-operated actuators are used for the player's fingers; this results in the compact music box.

36 Claims, 57 Drawing Sheets





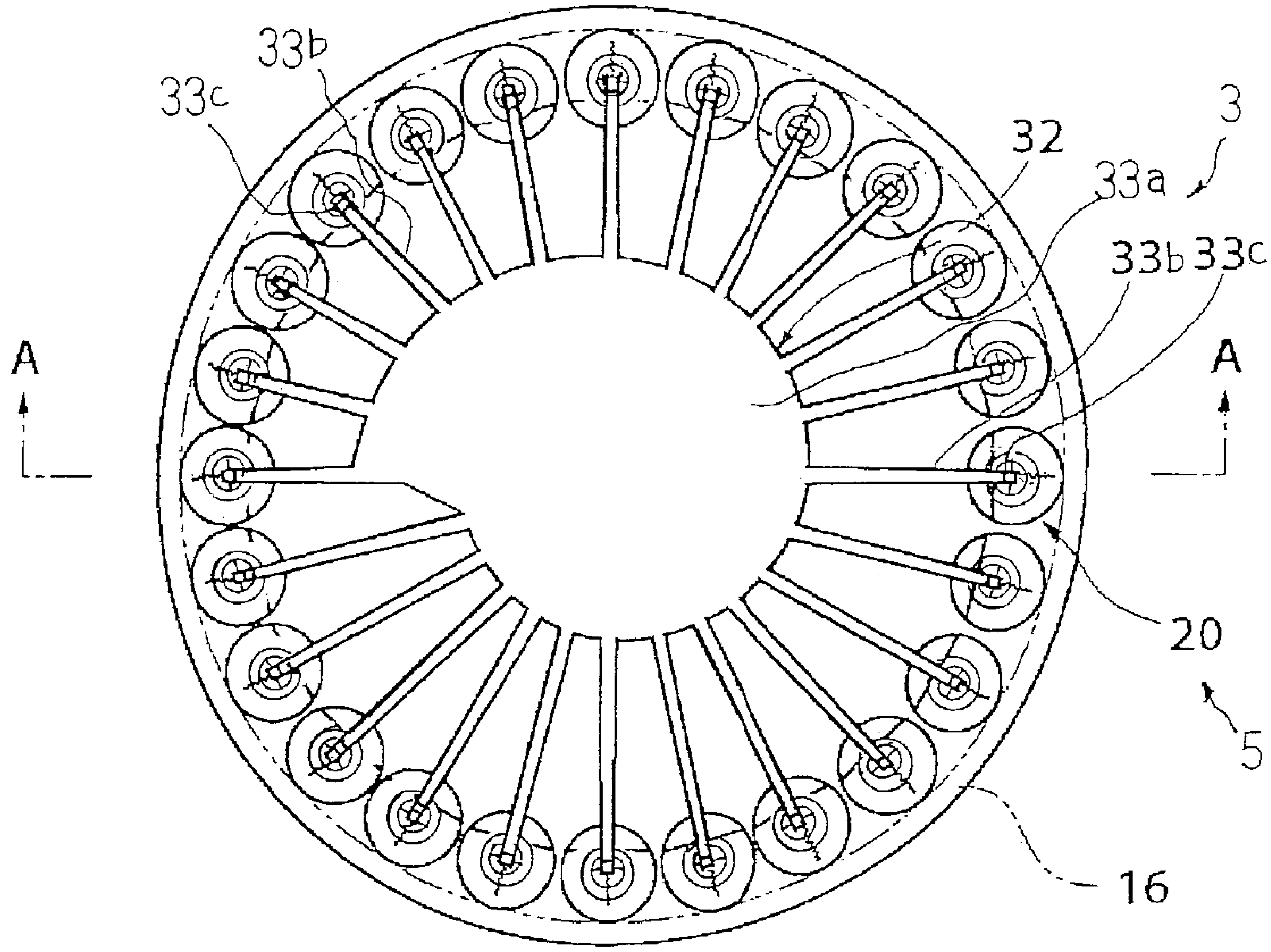

33b
33c
32
3
33a
33b 33c
A
A
20
5
16

Fig. 1A

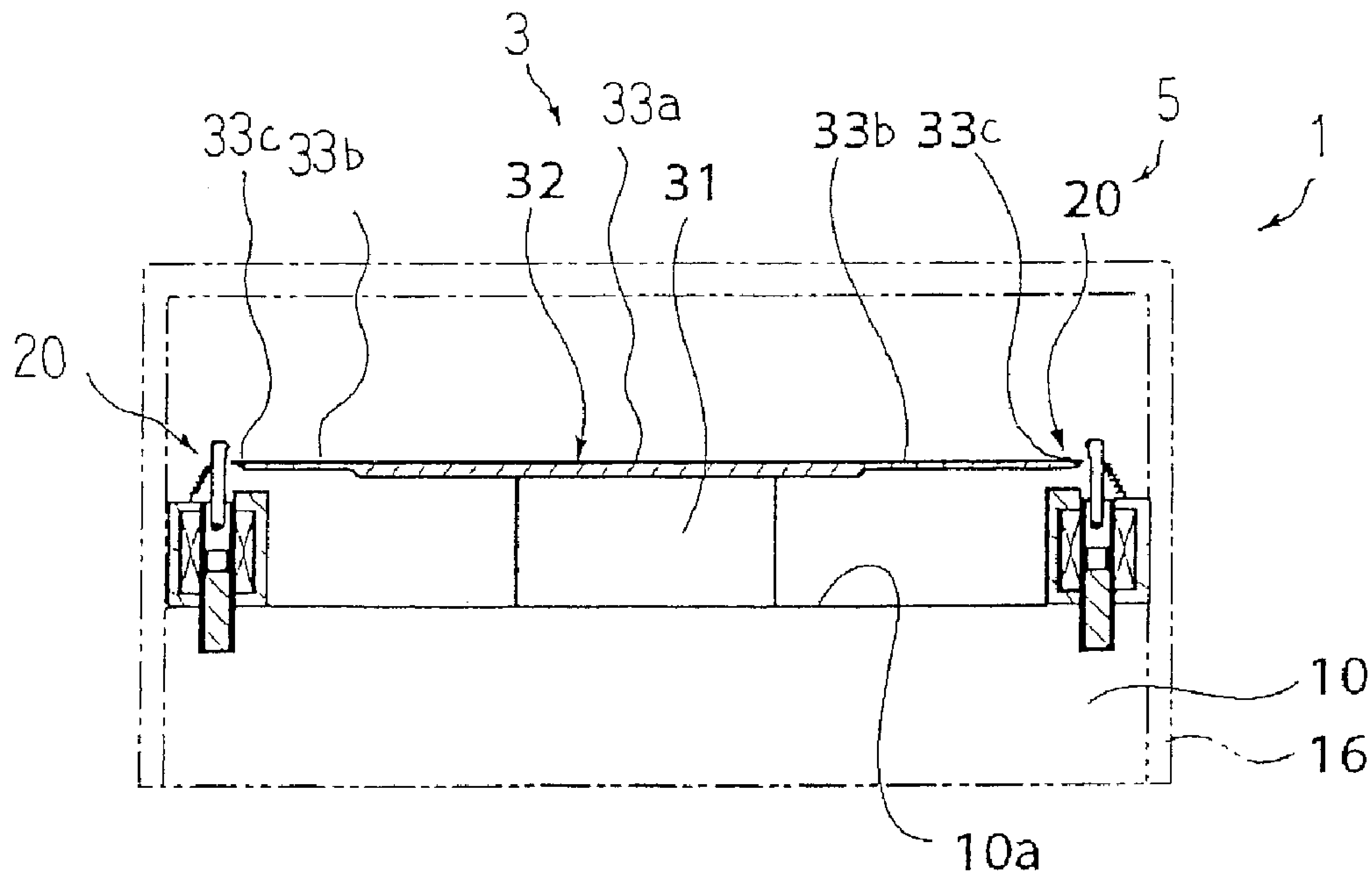
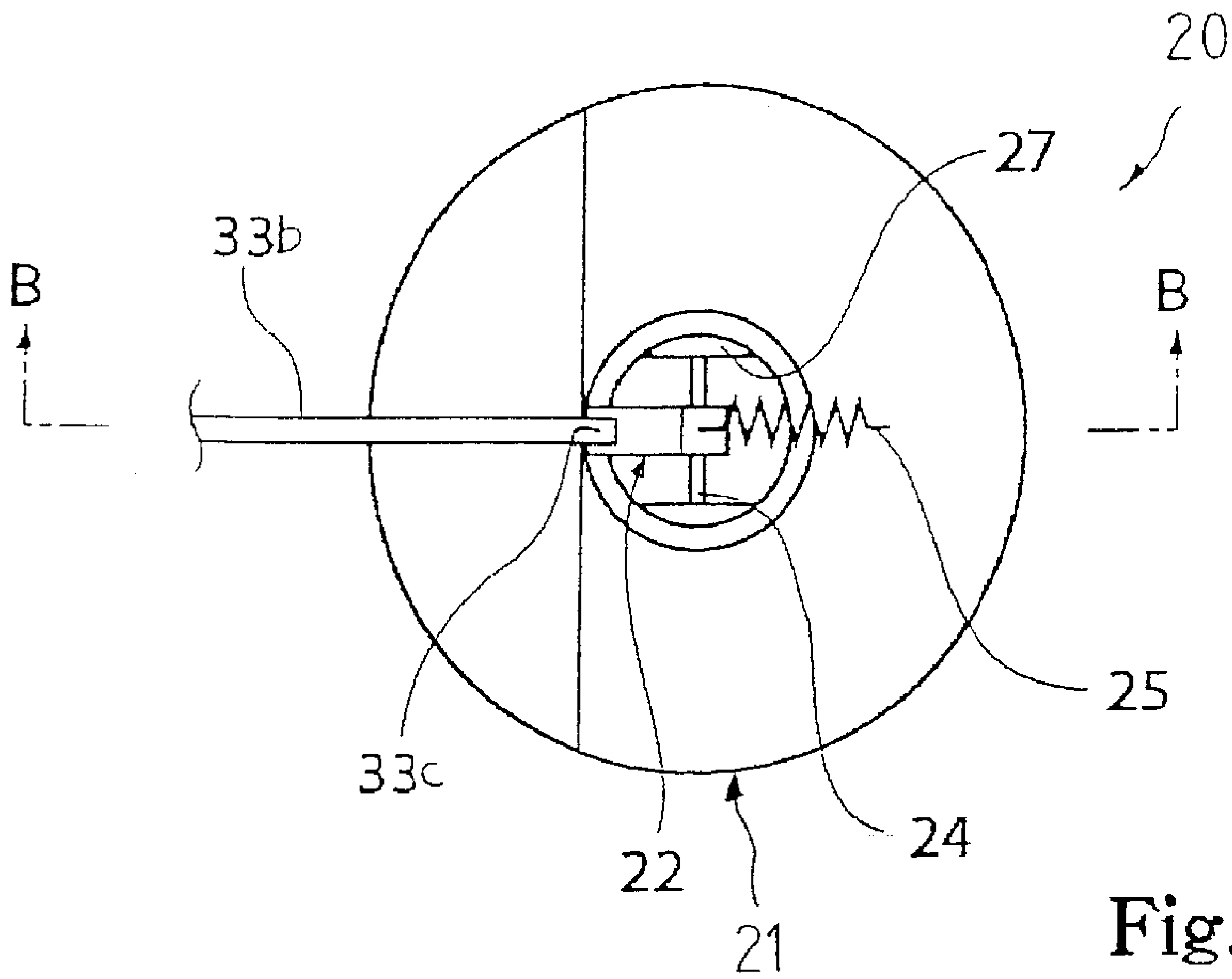

3
33a
5
33c 33b
33b 33c
1
32
31
20
20
10
16
10a

Fig. 1 B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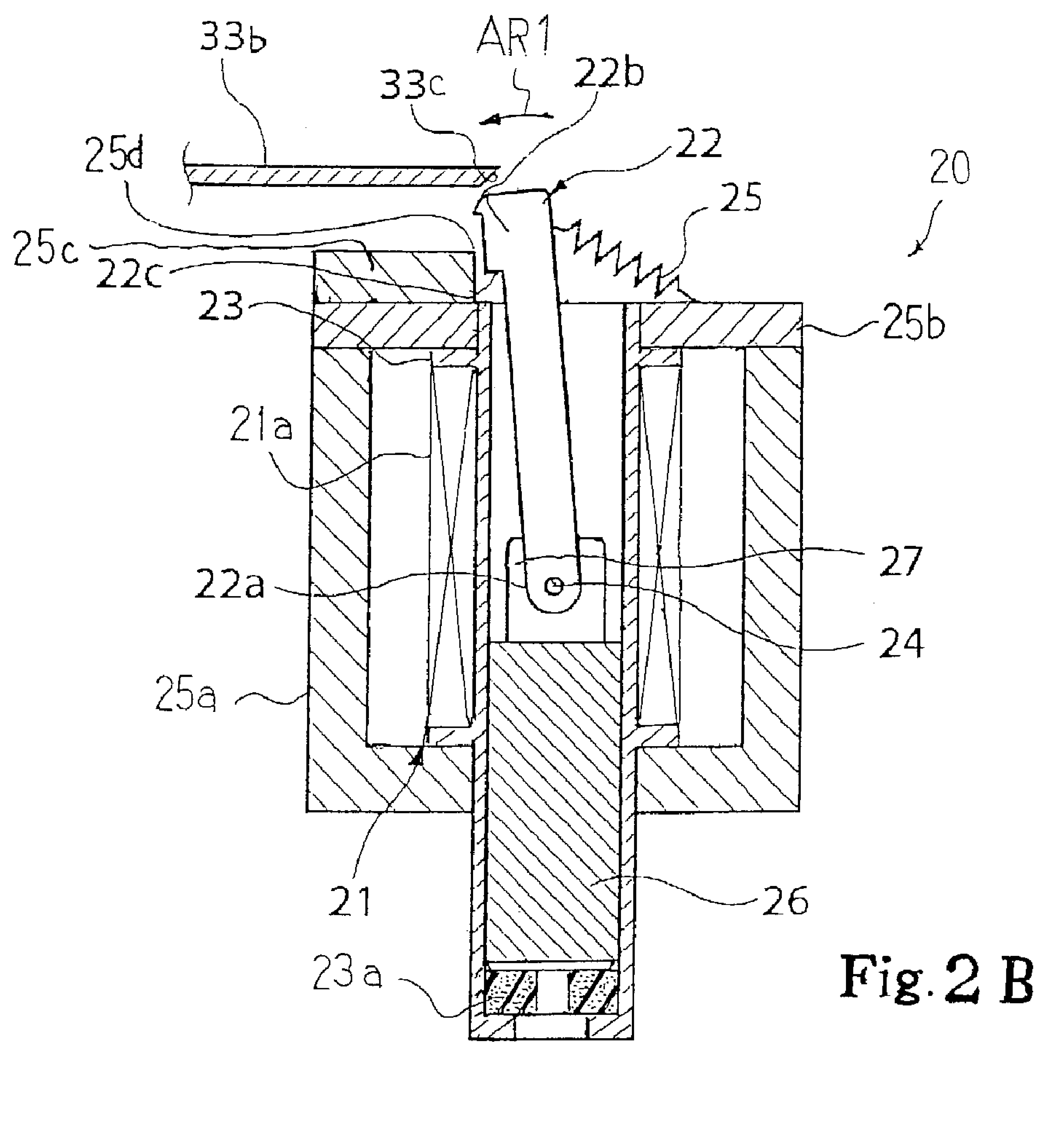
27
33b
B
B
25
33c
24
22
21

Fig. 2 A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AR1
33c
22b
25d
22
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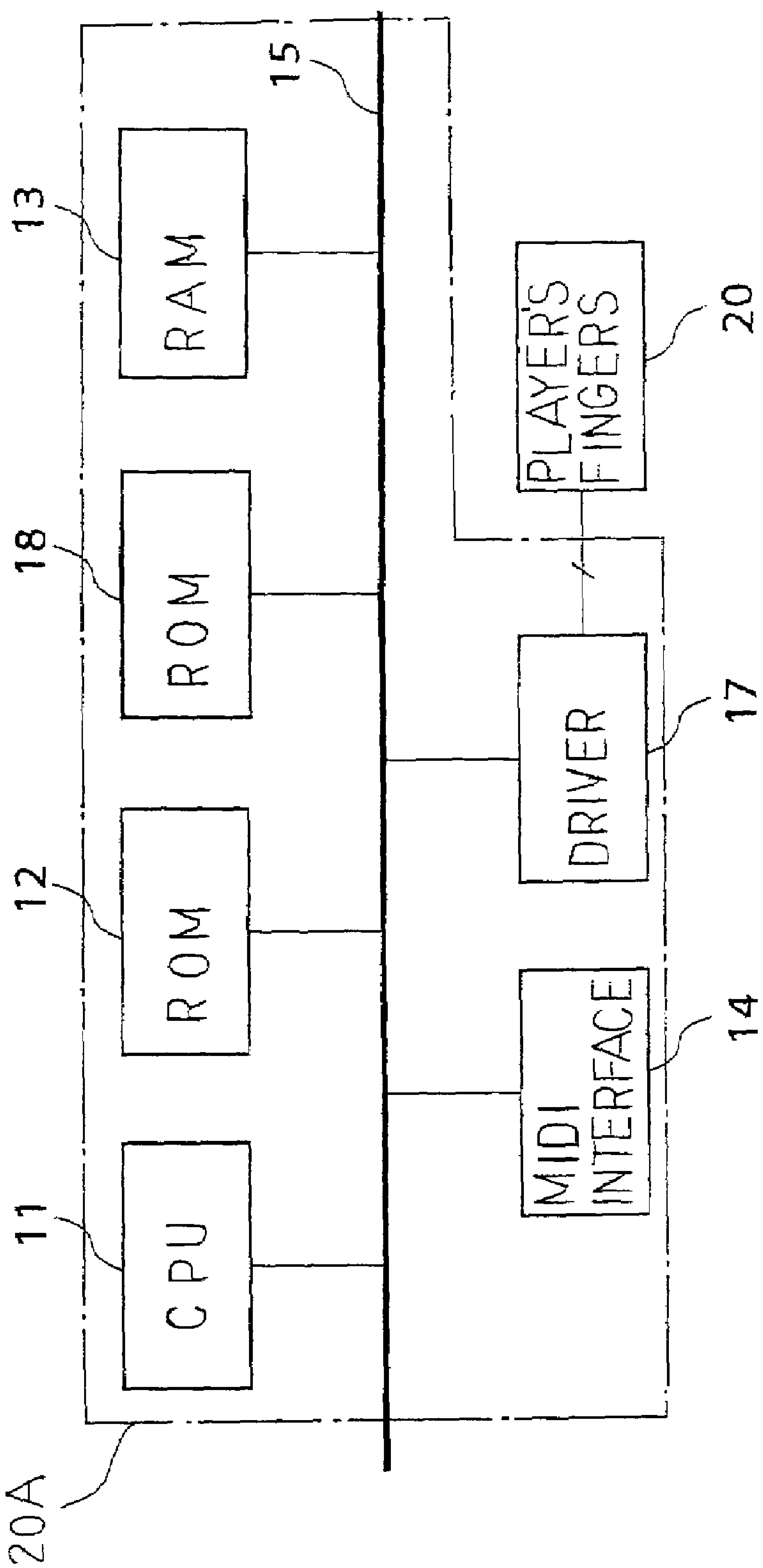
25
25c
22c
23
25b
21a
27
22a
24
25a
21
26
23a

Fig. 2 B



RAM
ROM
ROM
CPU
PLAYER'S FINGERS
DRIVER
MIDI INTERFACE
13
18
12
11
15
20
17
14
20A

Fig. 3

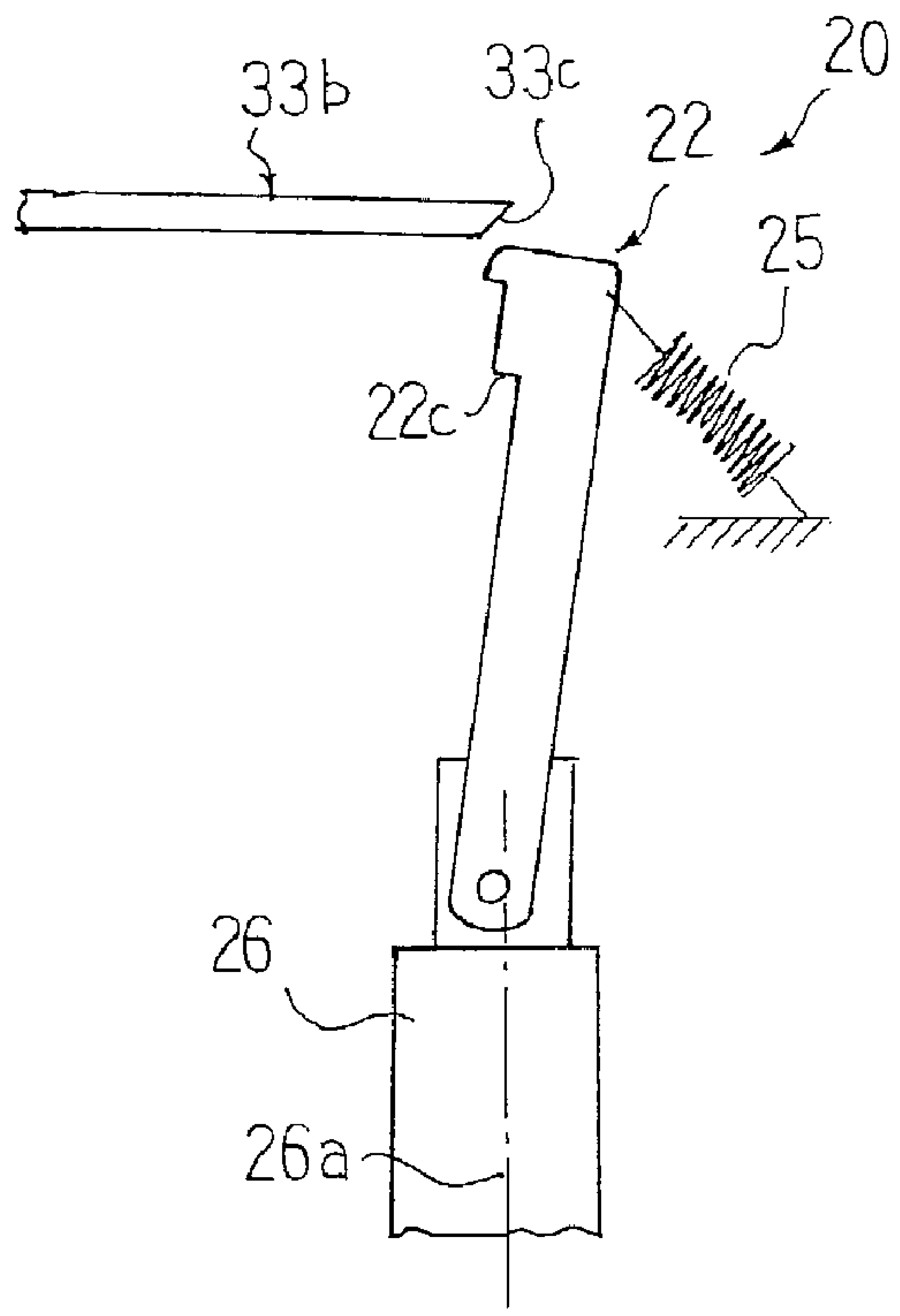


Fig. 4A

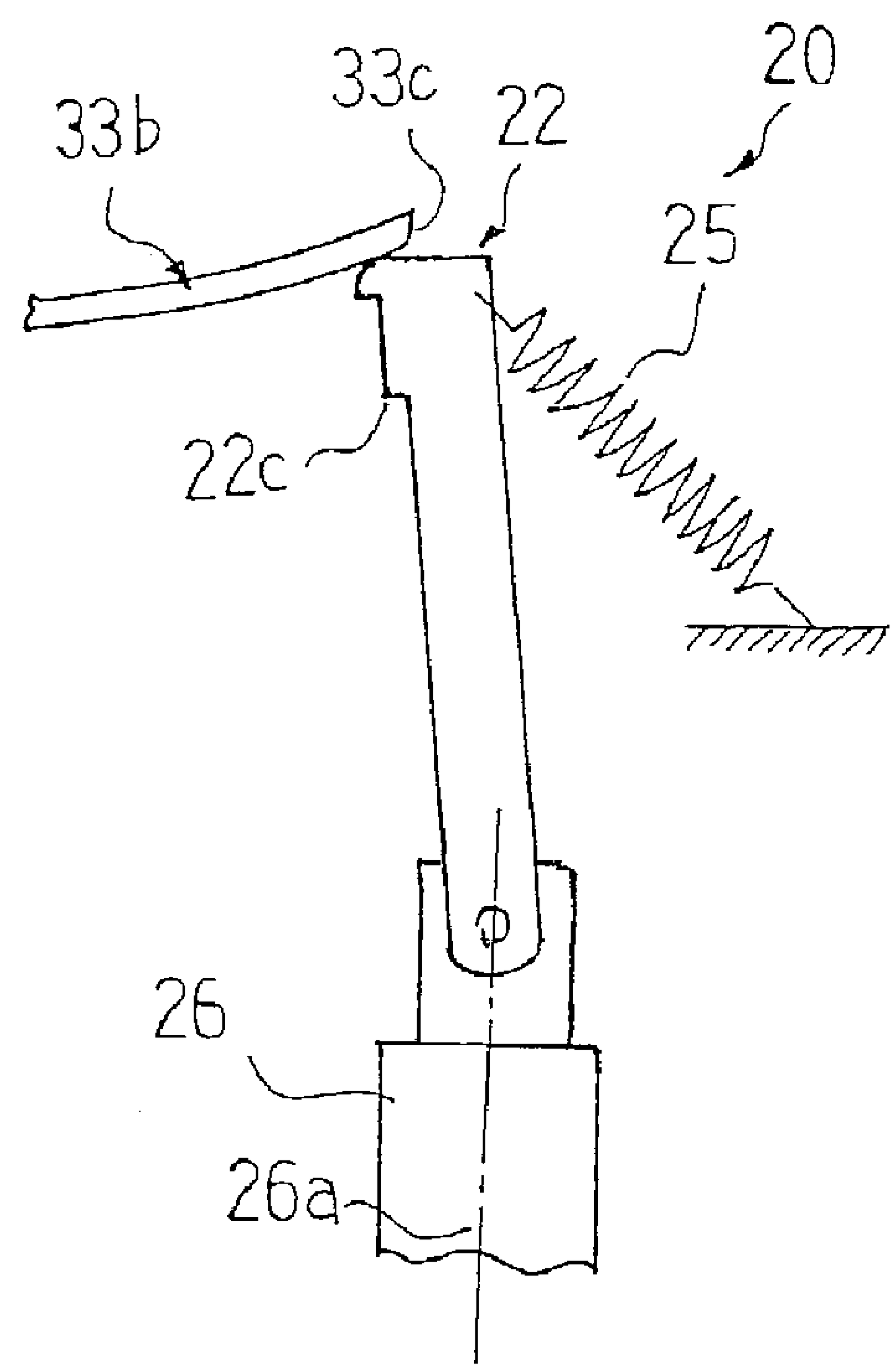


Fig. 4B

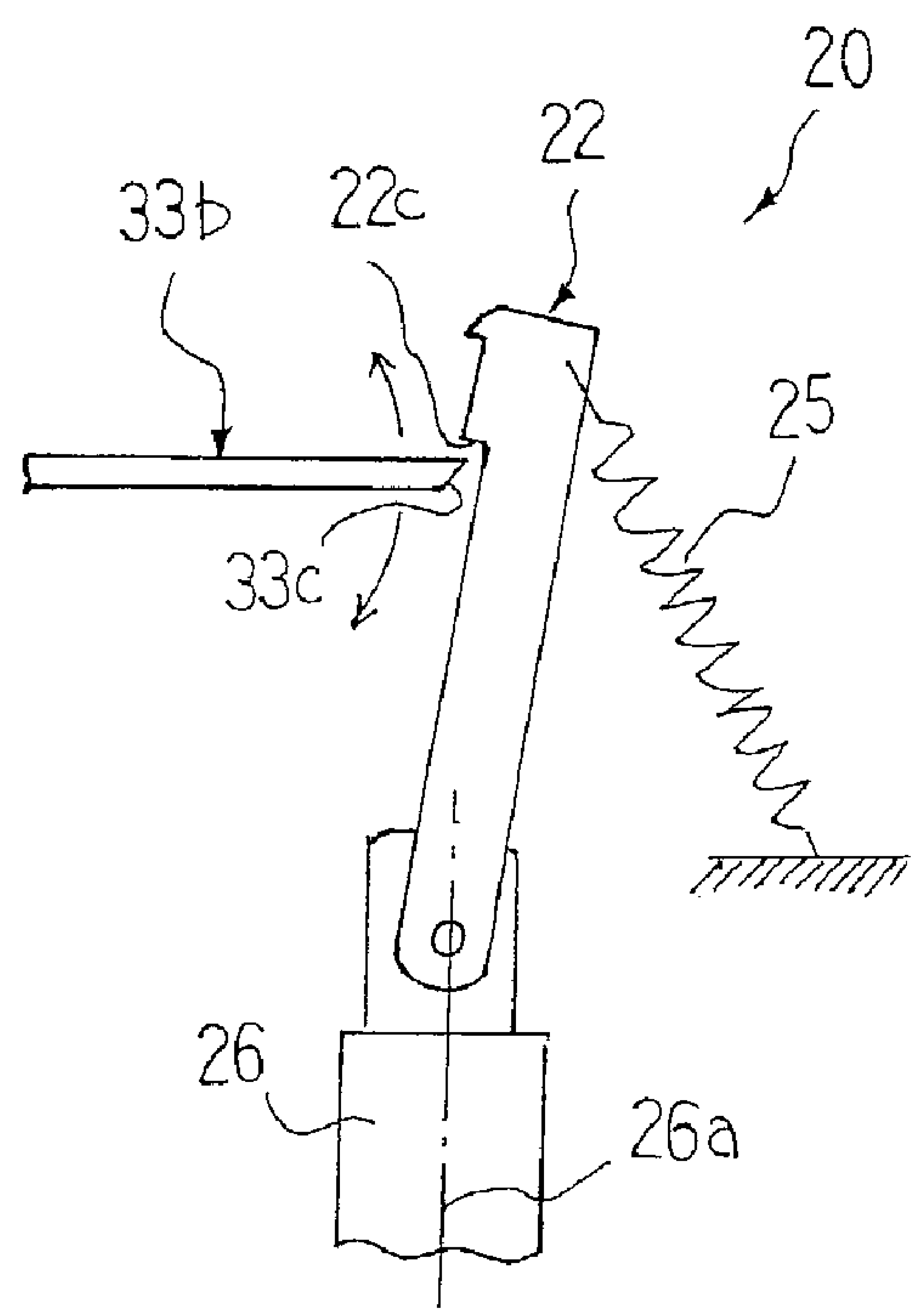


Fig. 4C

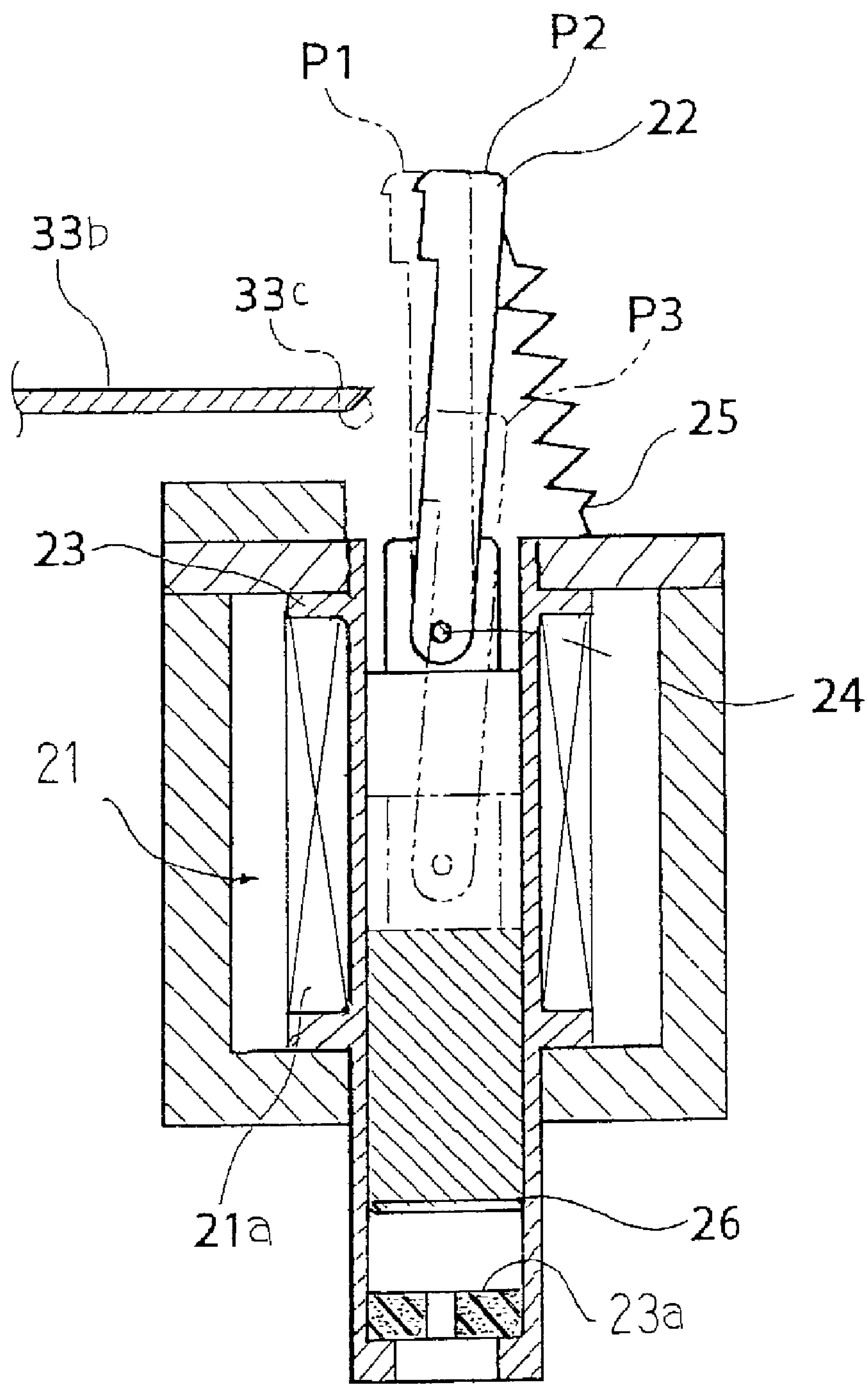


Fig. 5

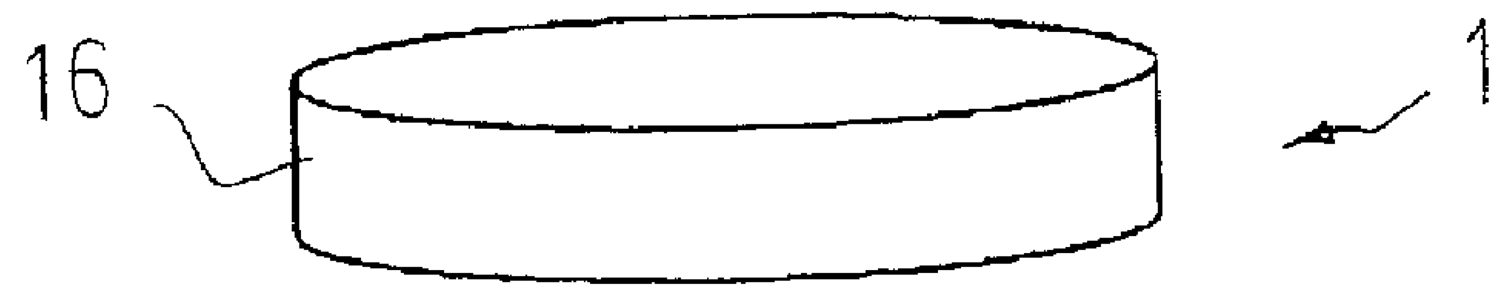


Fig. 6 A

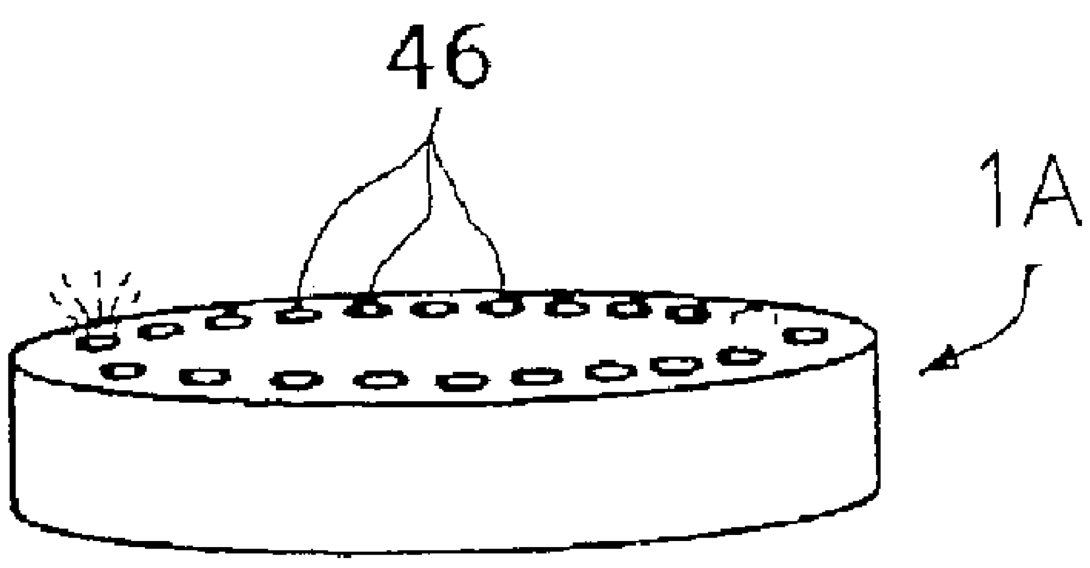


Fig. 6 B

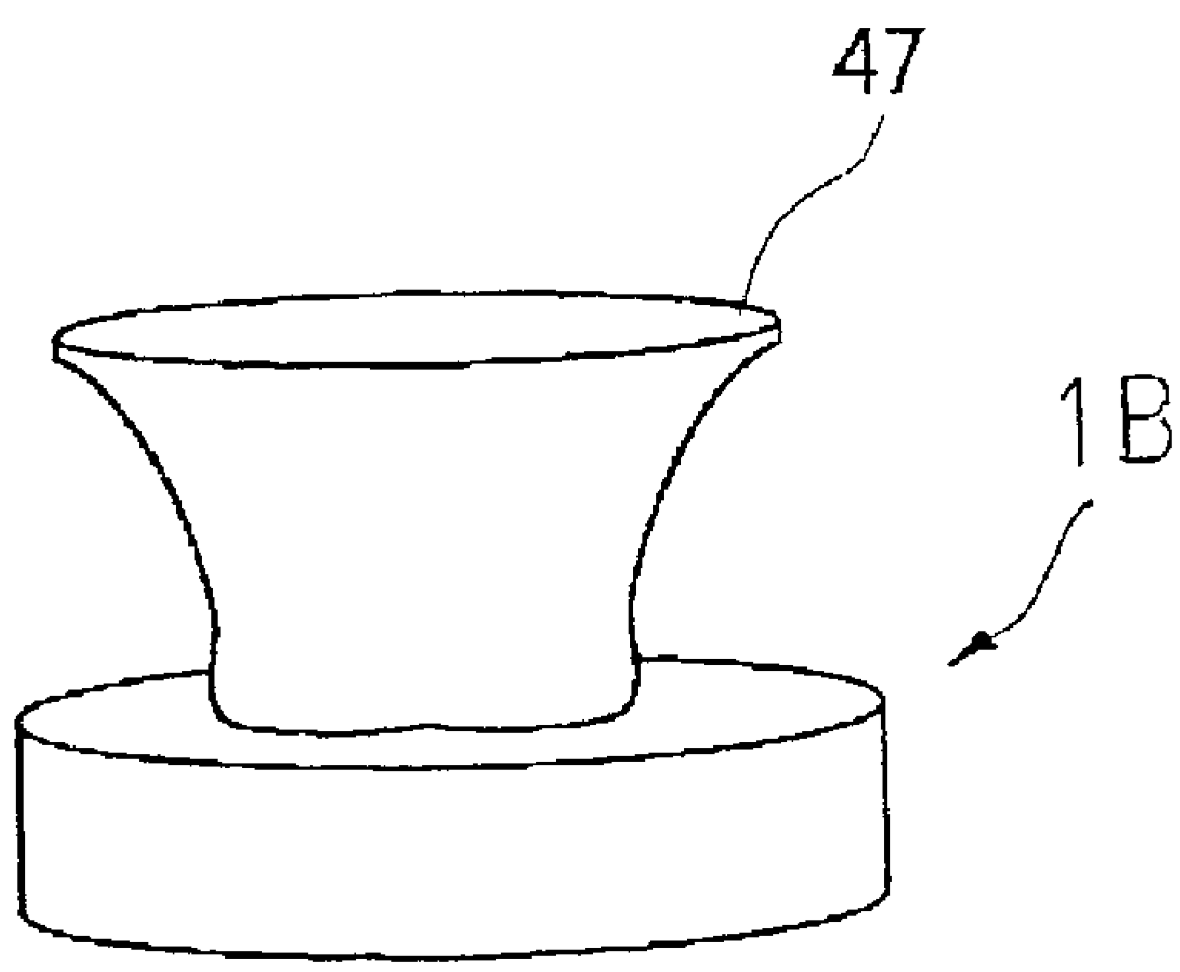


Fig. 6 C

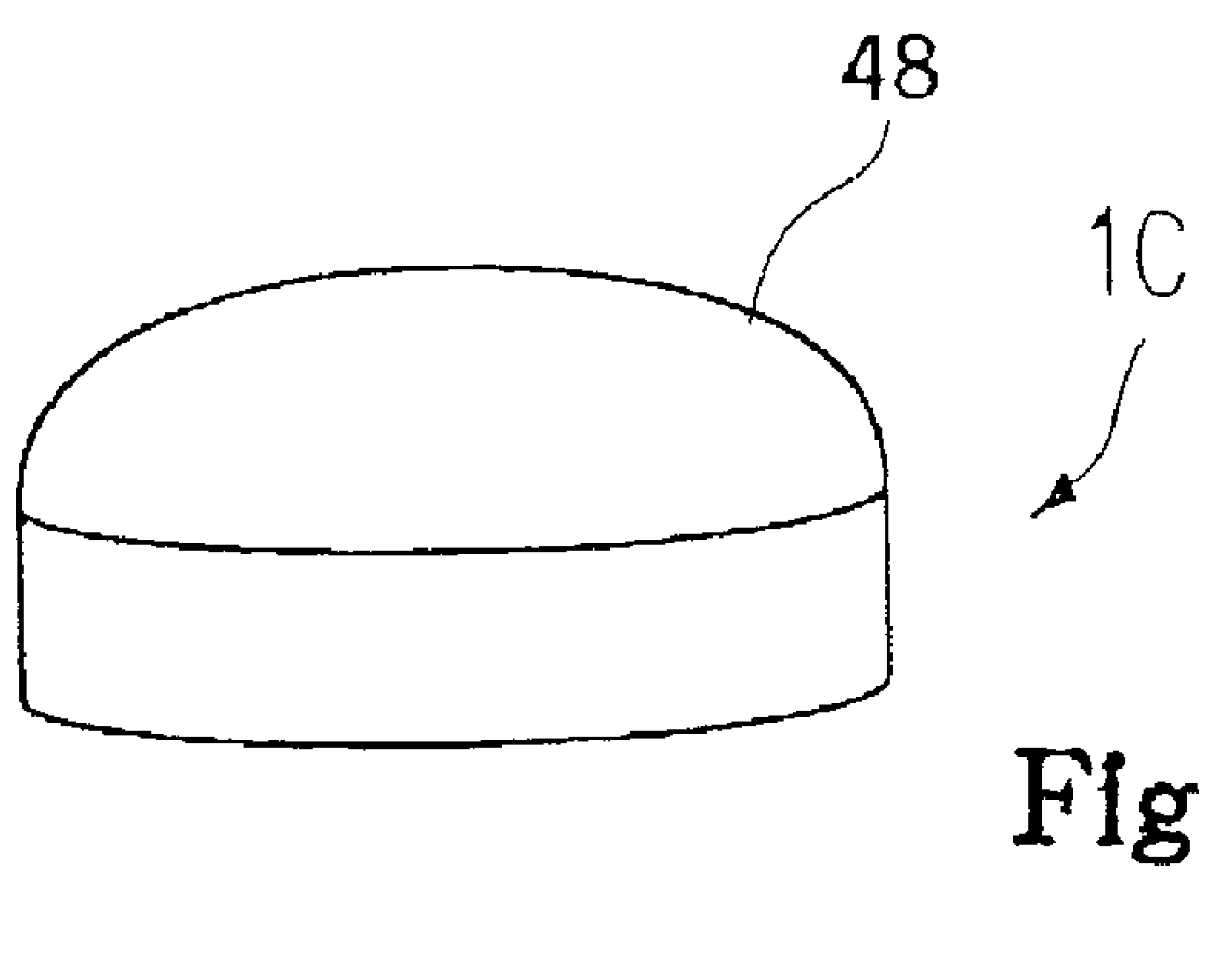
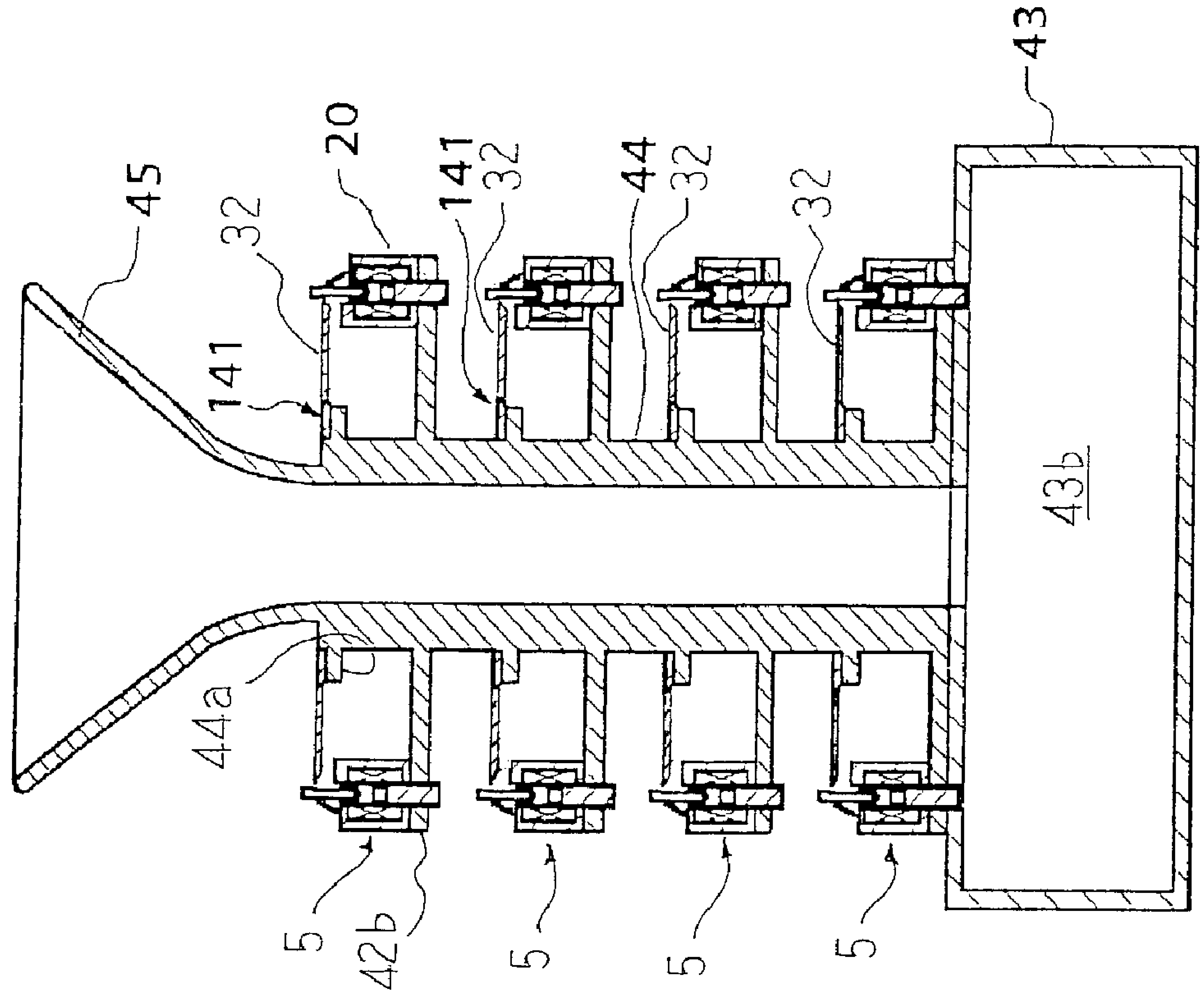
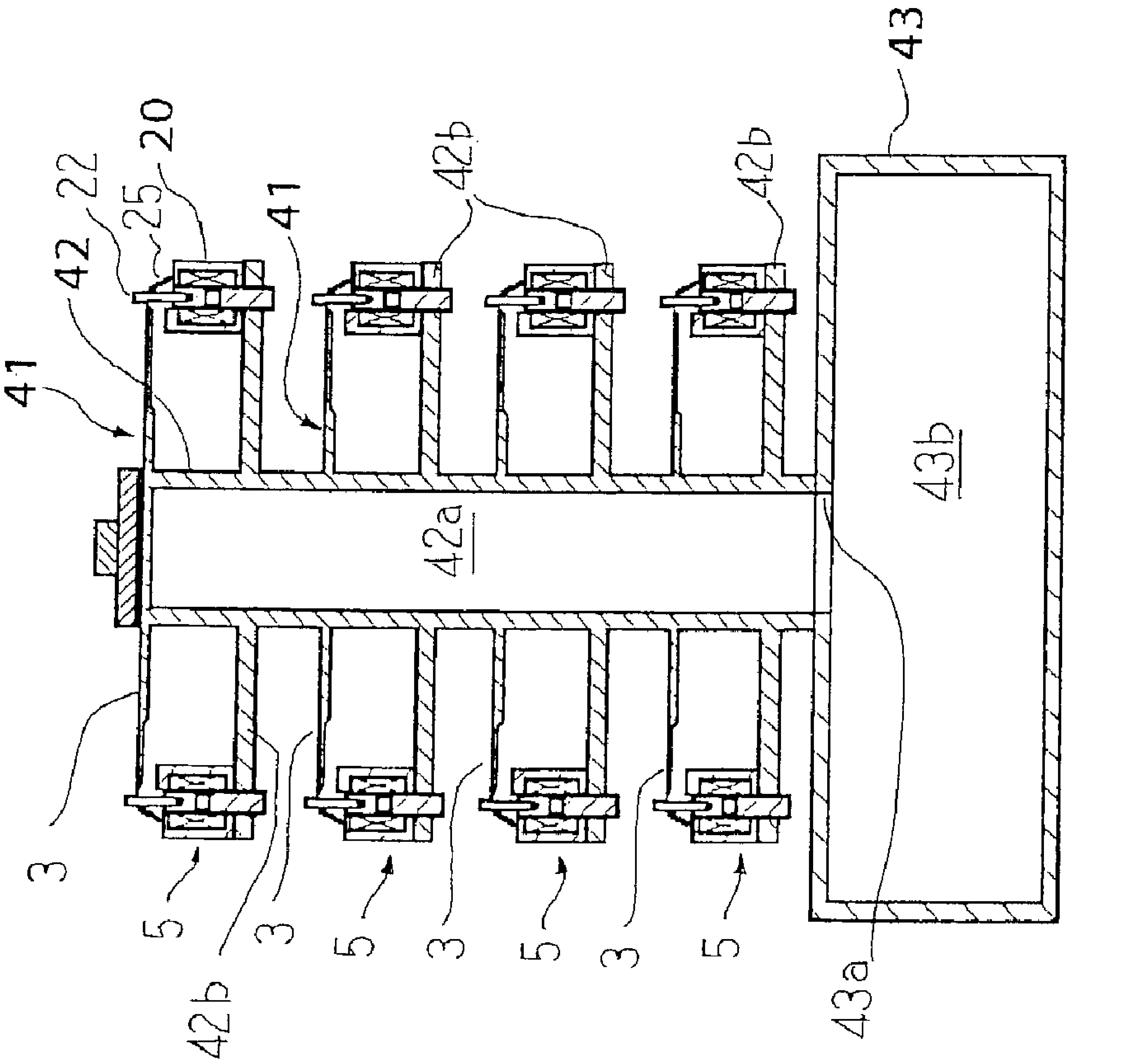


Fig. 6 D



45
32
141
20
141
32
44
32
32
43
44a
43b
5
42b
5
5
5

Fig. 7 B



41
42
22
25
20
41
42b
42b
42b
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42a
43b
3
5
42b
3
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3
5
43a

Fig. 7 A

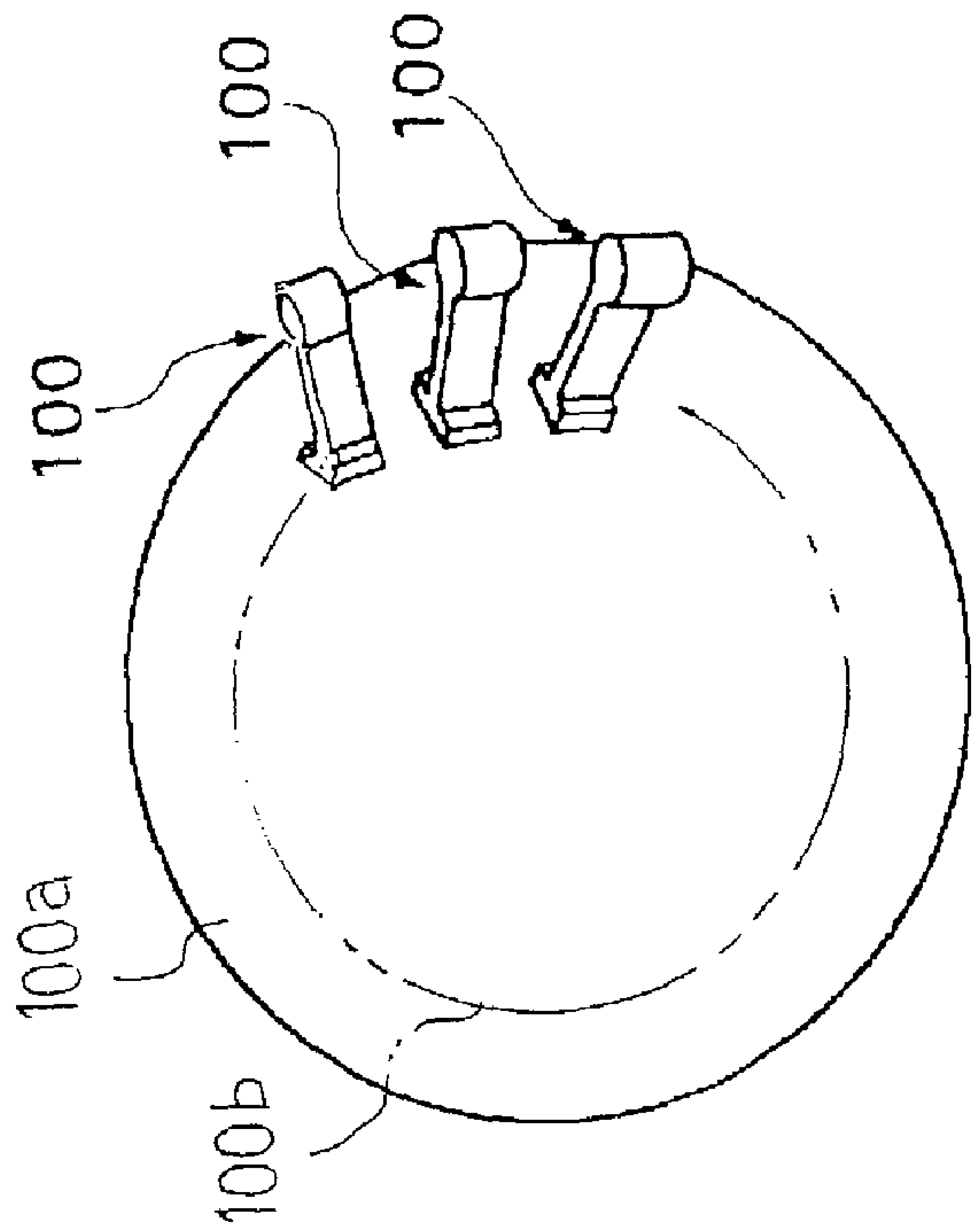
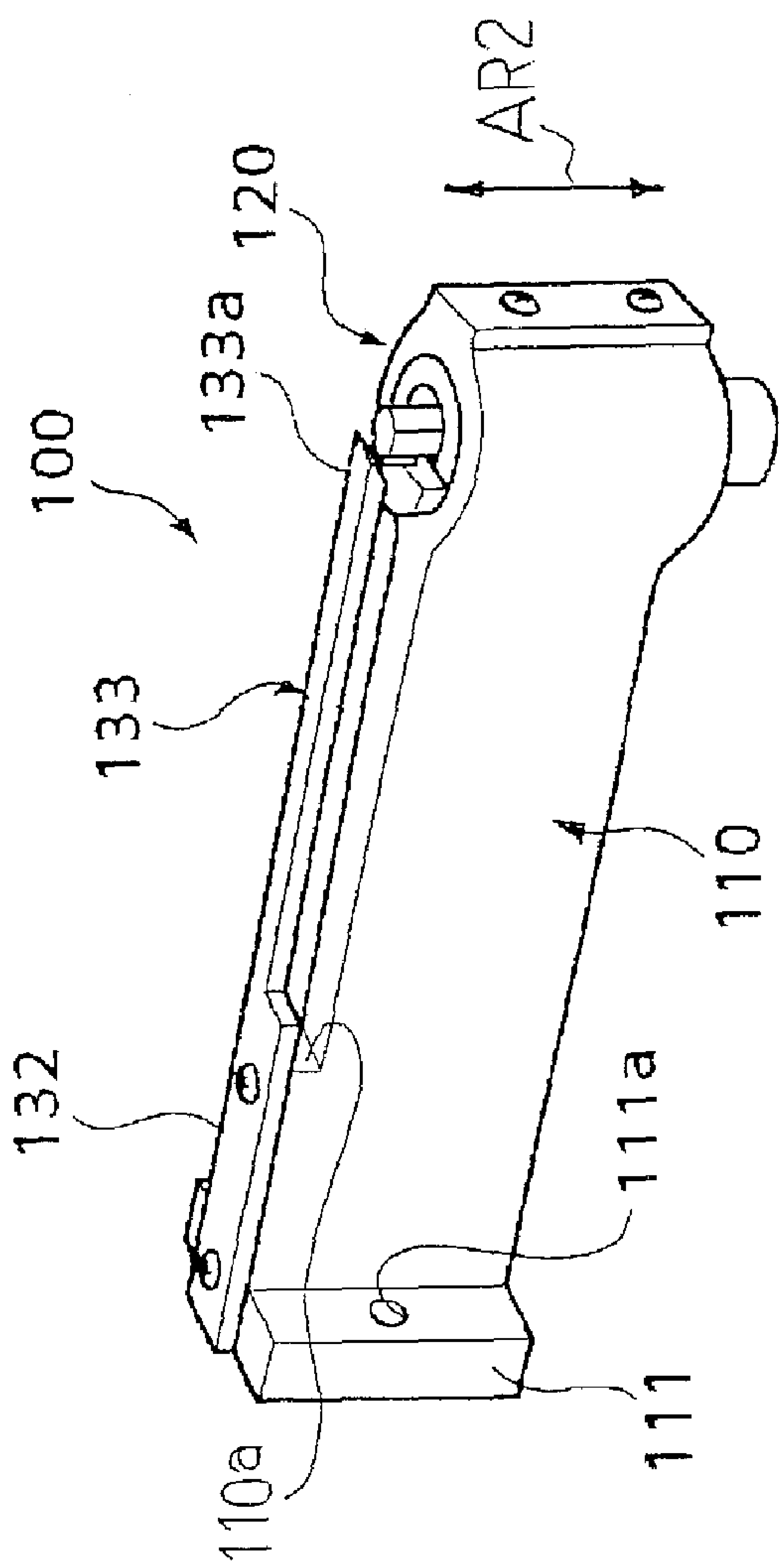

100
100
100
100a
100b

Fig. 8B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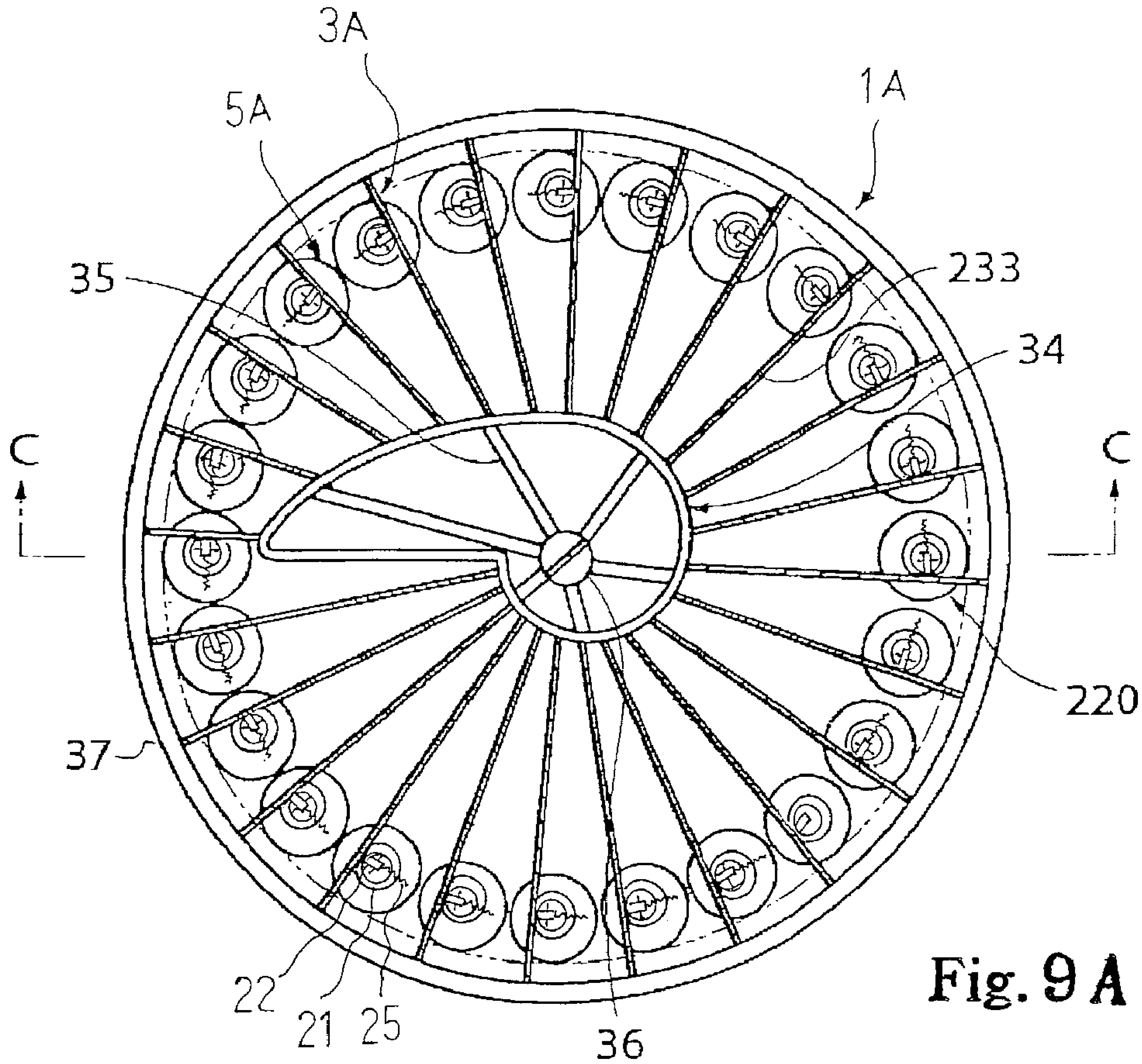
AR2
133
110
132
111a
111
110a

Fig. 8A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5A
1A
35
233
34
C
C
220
37
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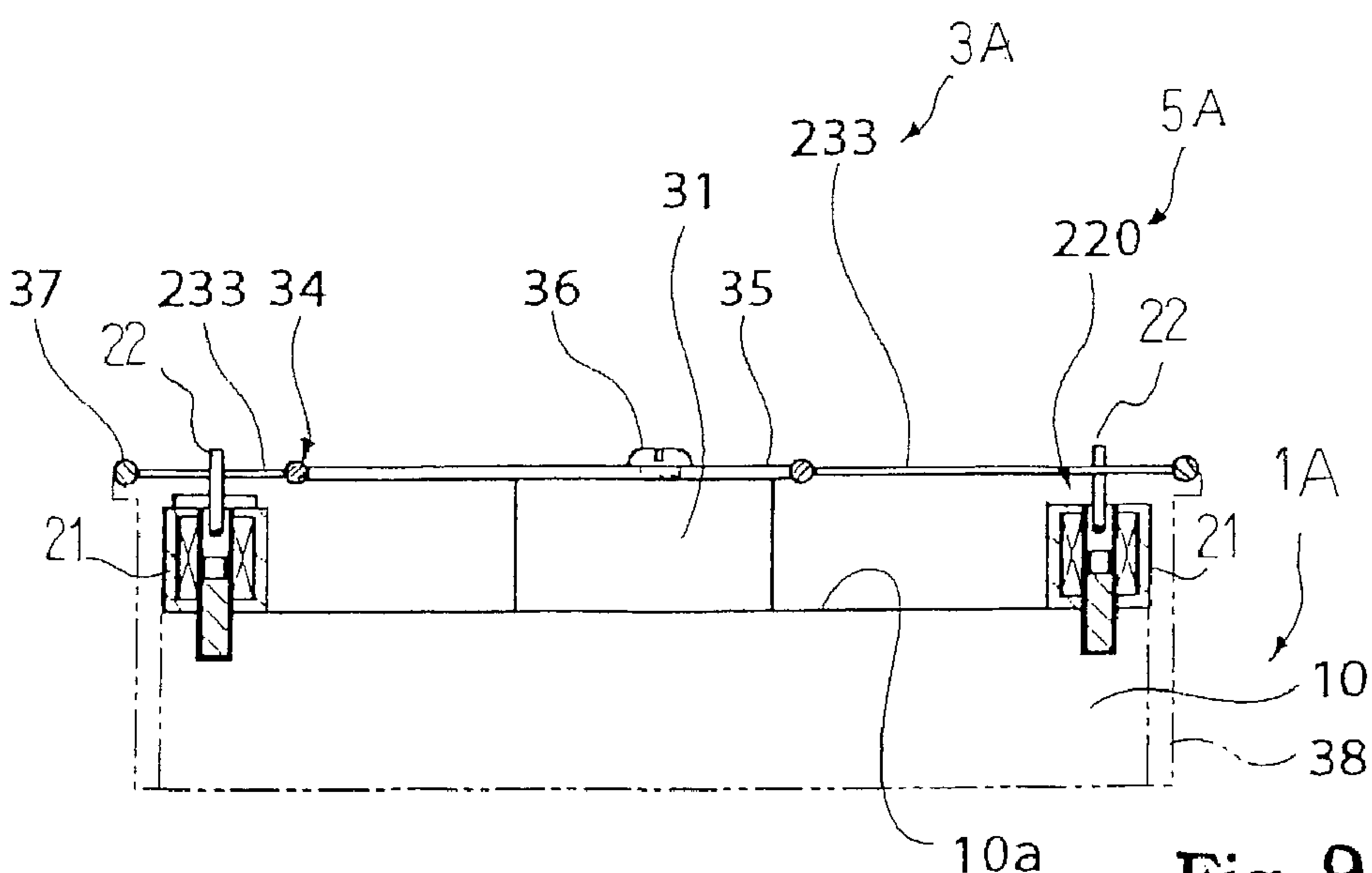
21
25
36

Fig. 9 A


3A
233
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37
233
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36
35
22
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1A
21
21
10
38
10a

Fig. 9 B

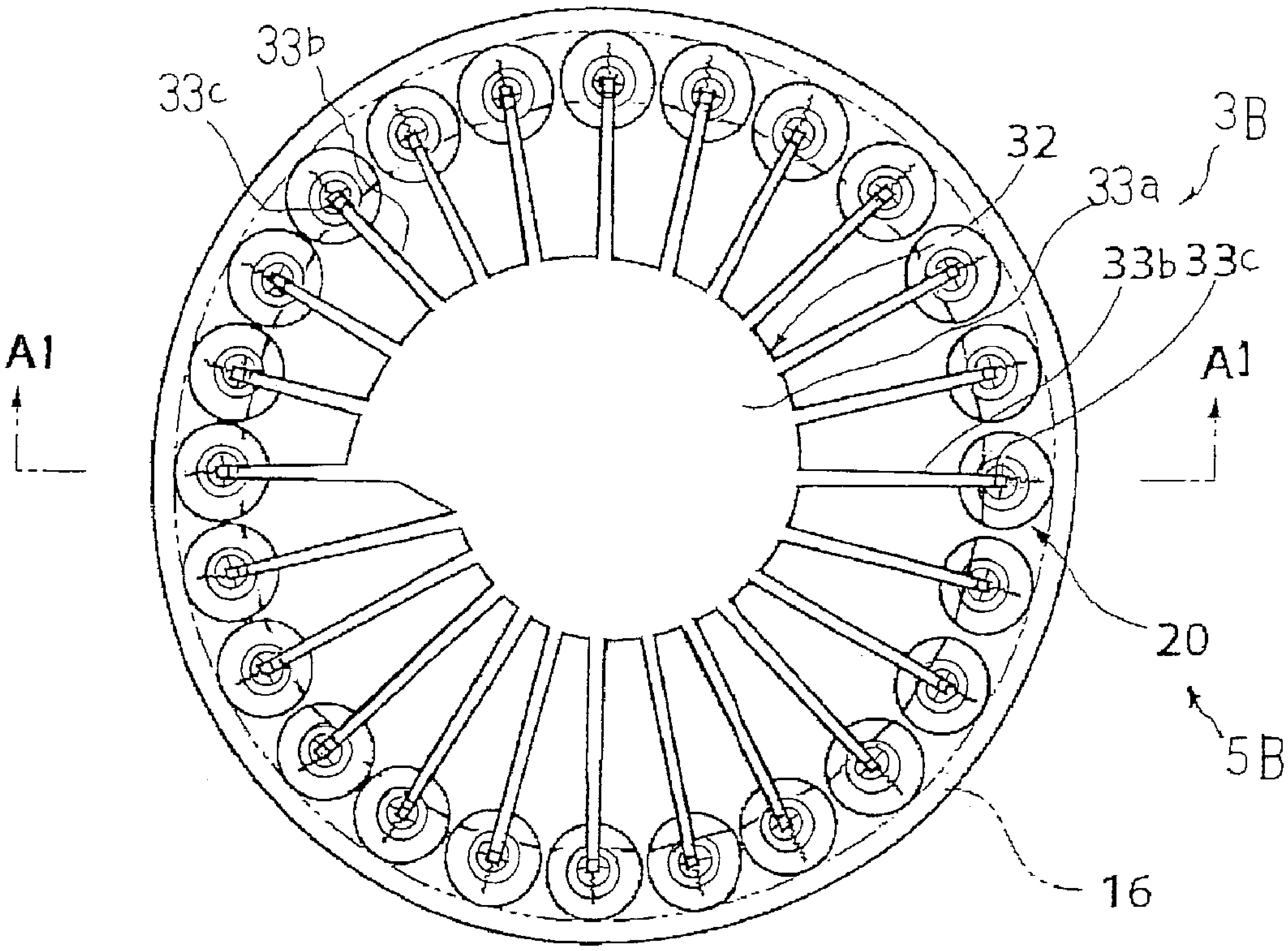
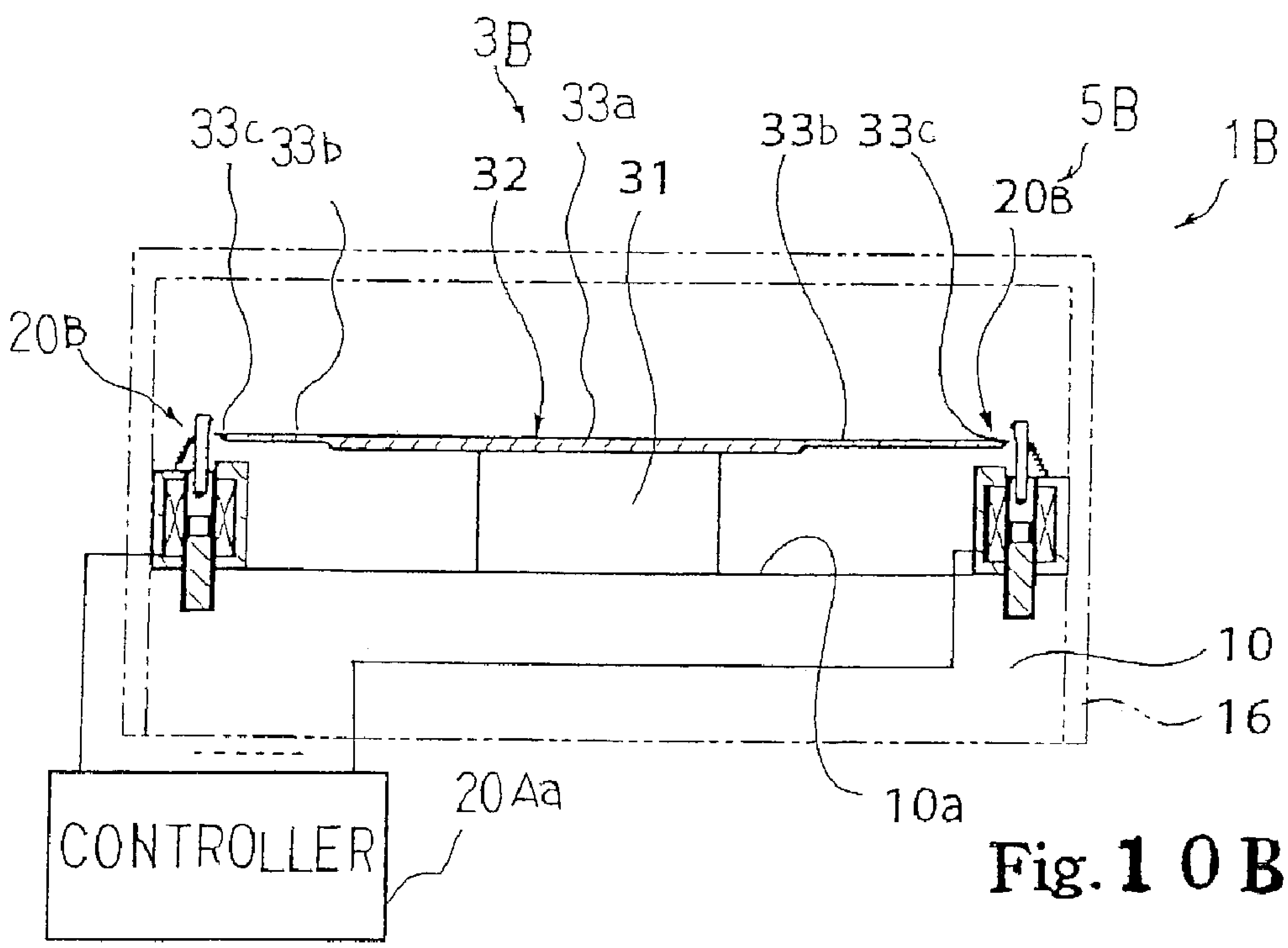


Fig. 10A



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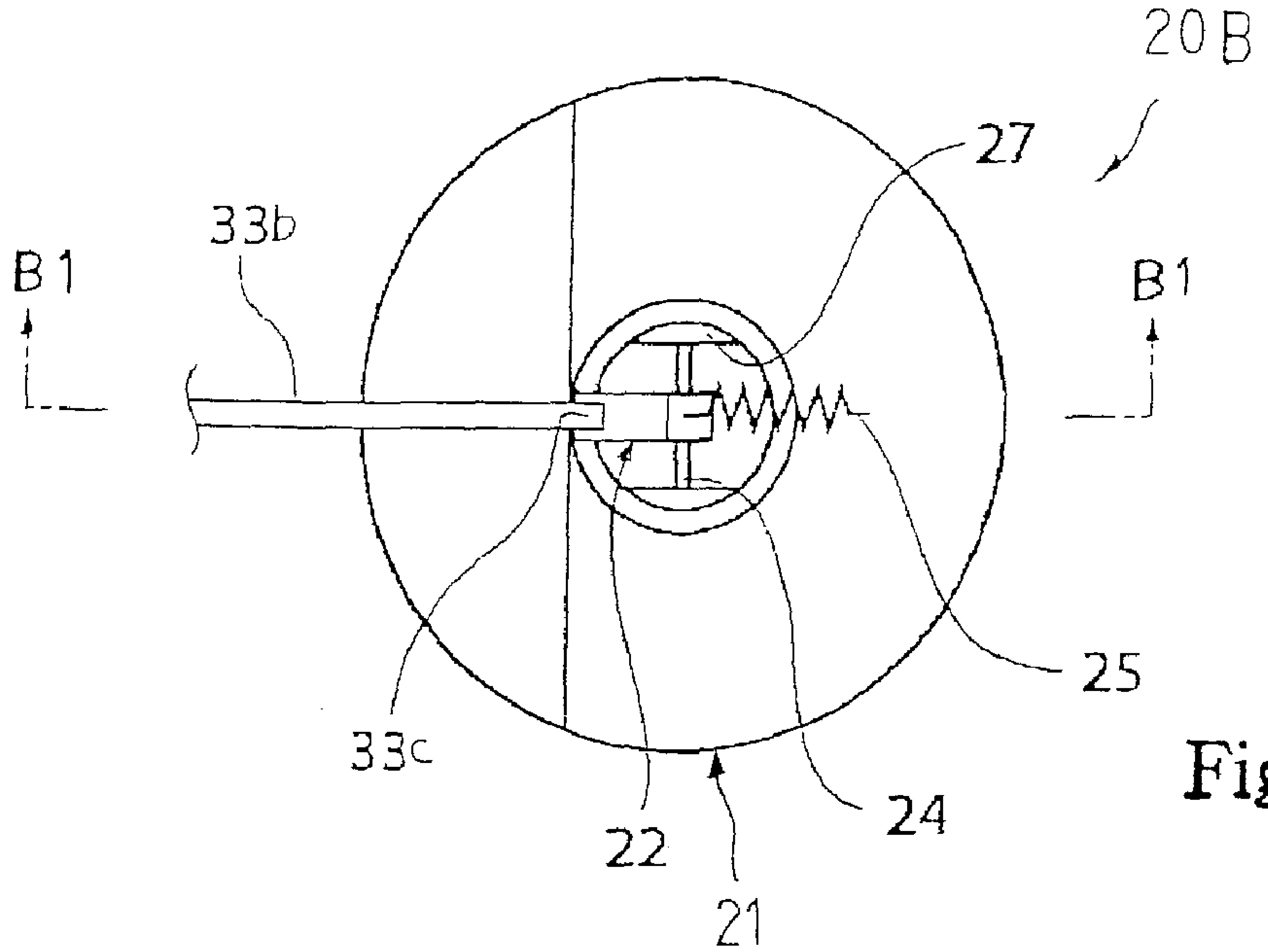


Fig. 11 A

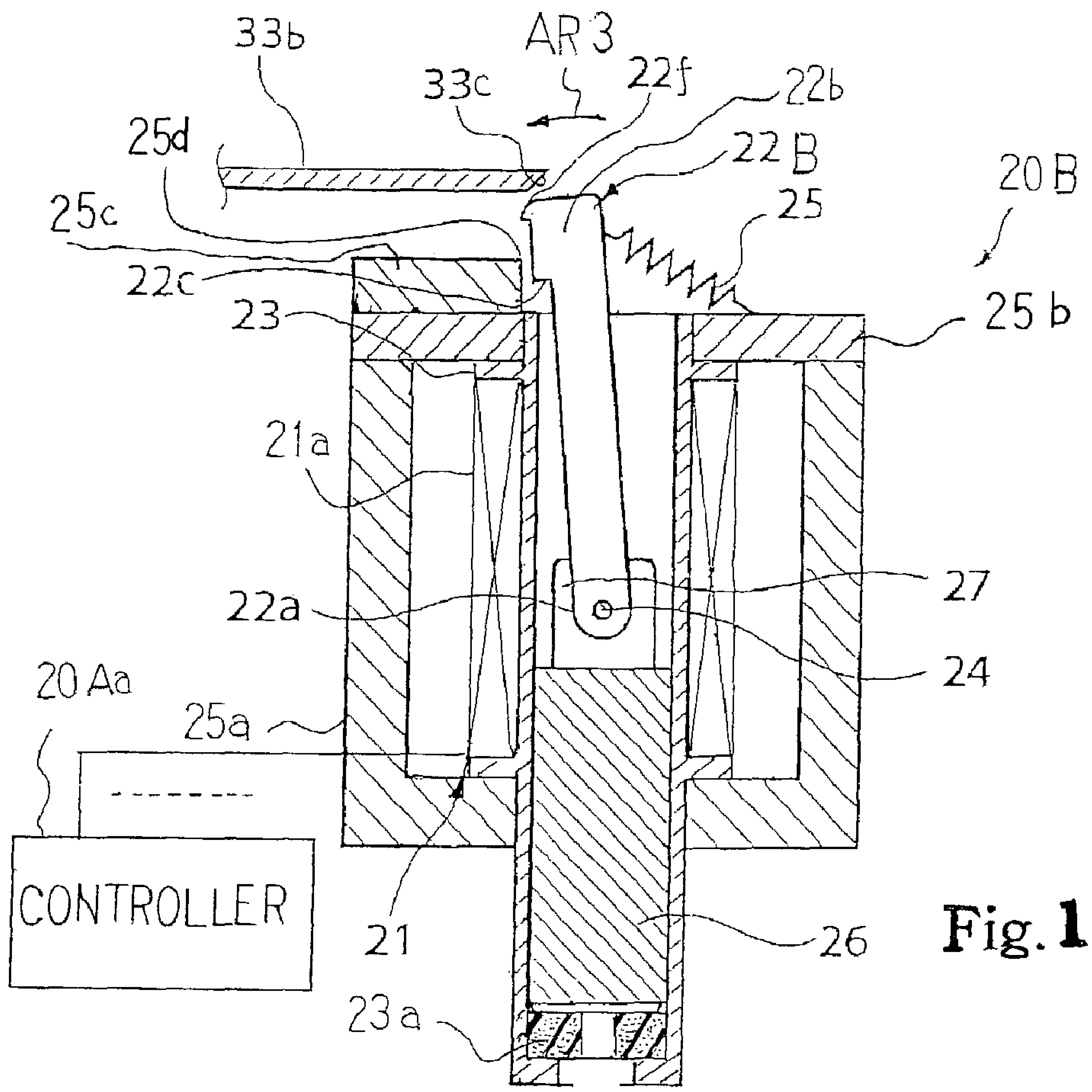
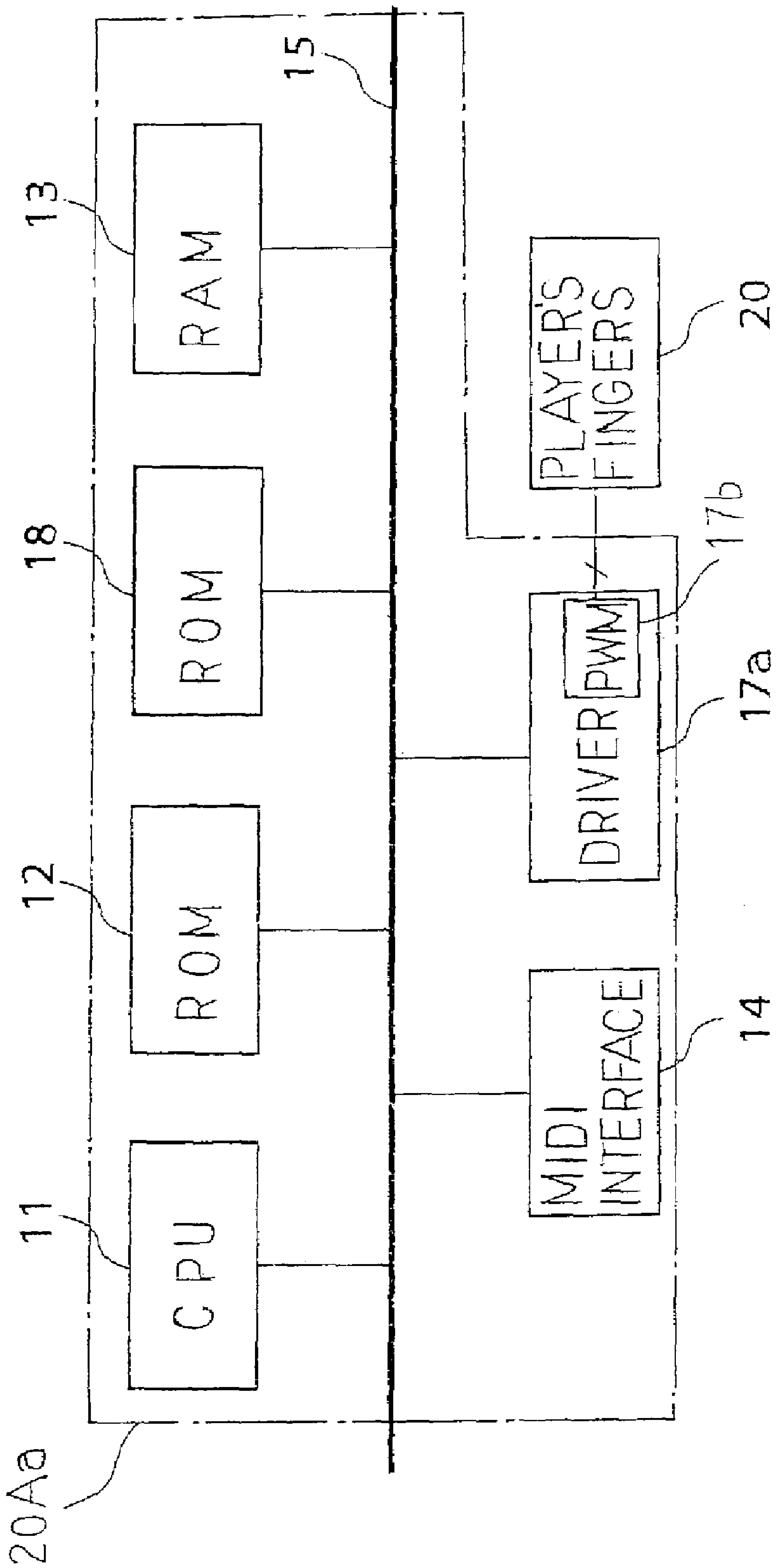


Fig. 11 B



20Aa
11
CPU
12
ROM
18
ROM
13
RAM
15
MIDI INTERFACE
14
DRIVER
PWM
17a
17b
PLAYER'S FINGERS
20

Fig. 12

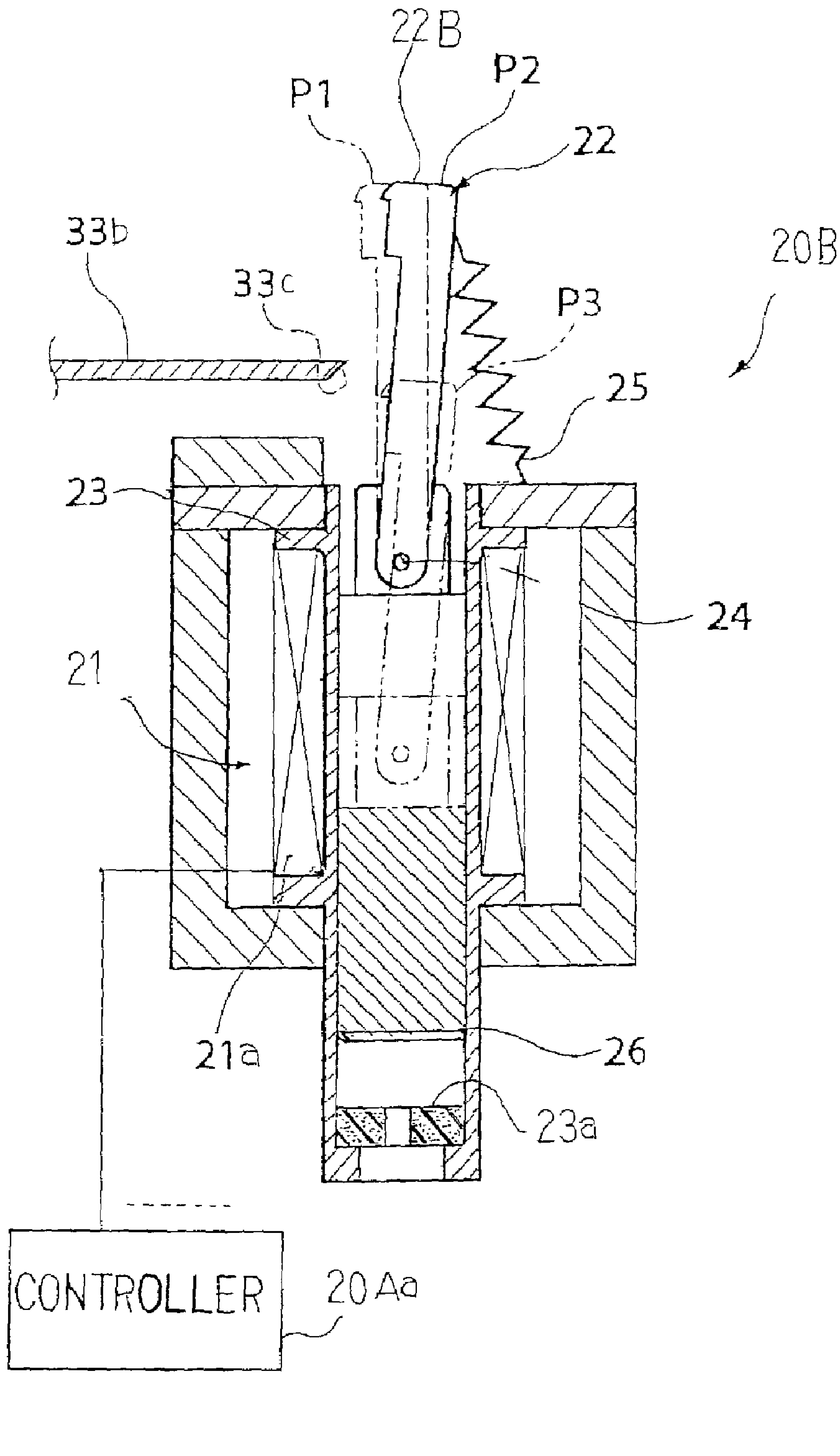

22B
P2
P1
22
33b
33c
20B
P3
25
23
24
21
21a
26
23a
CONTROLLER
20Aa

Fig. 13

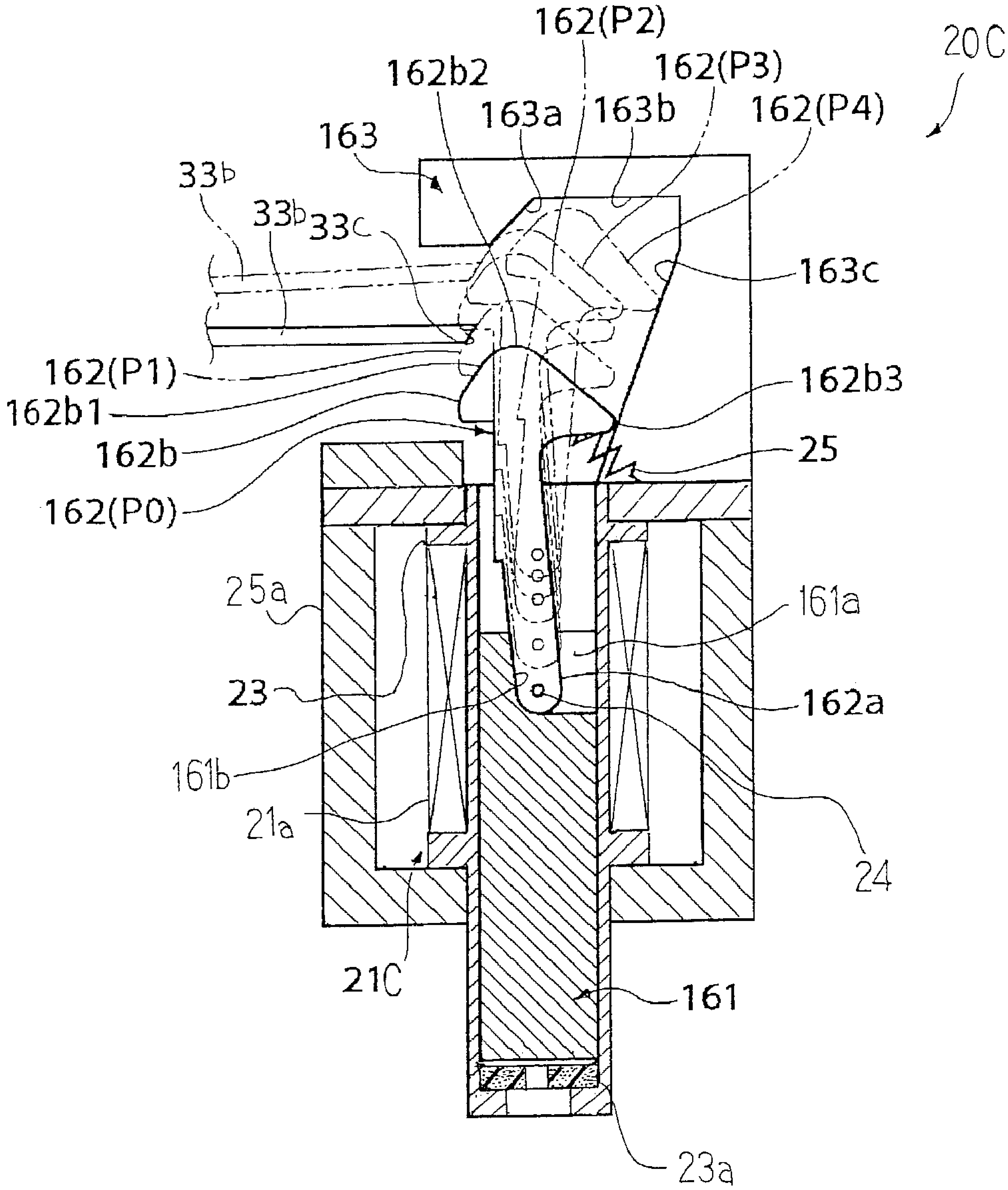

162(P2)
20C
162b2
162(P3)
163a
163b
162(P4)
163
33b
33b
33c
163c
162(P1)
162b3
162b1
162b
25
162(P0)
25a
161a
23
162a
161b
21a
24
21C
161
23a

Fig. 14

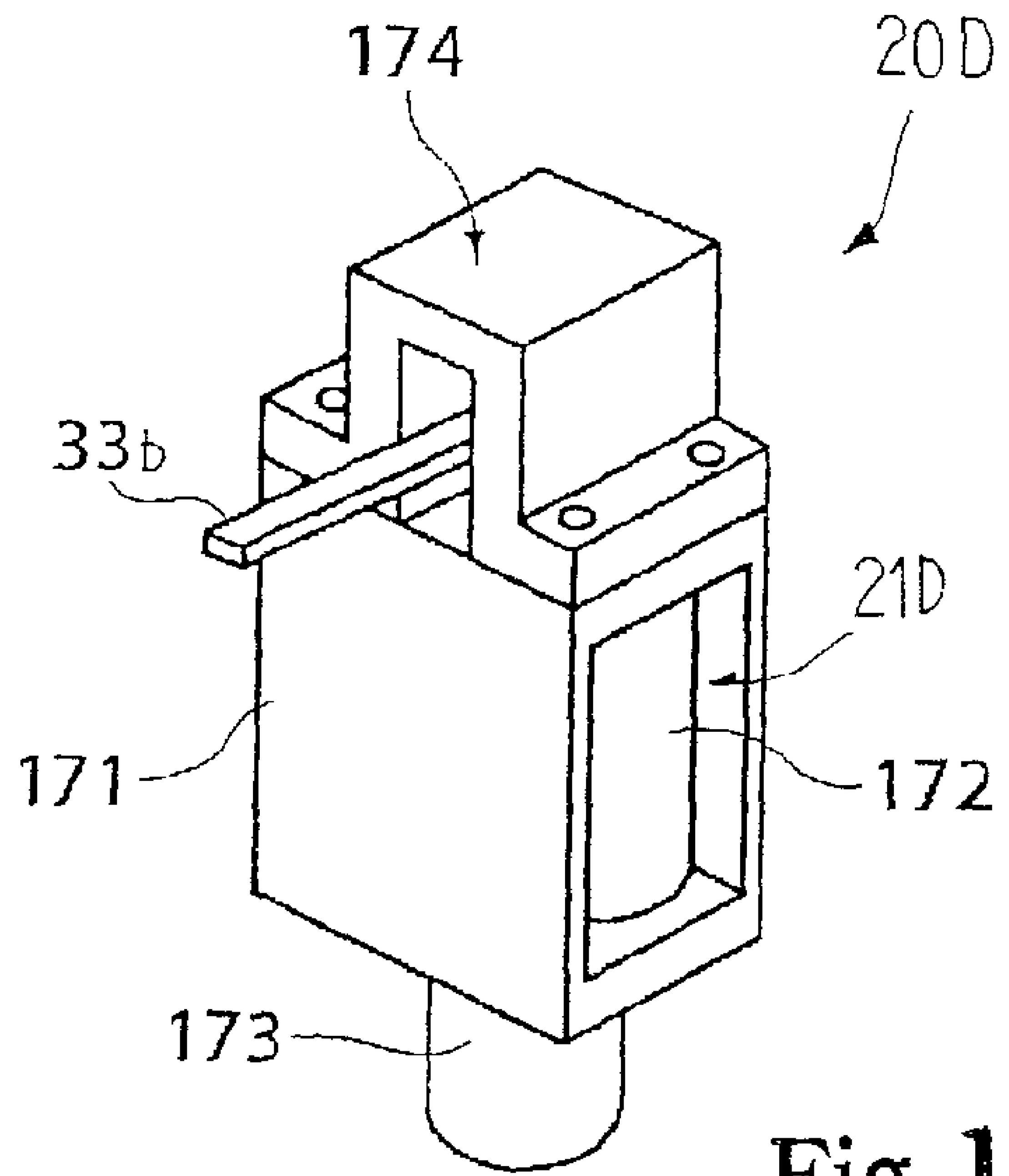


Fig. 15A

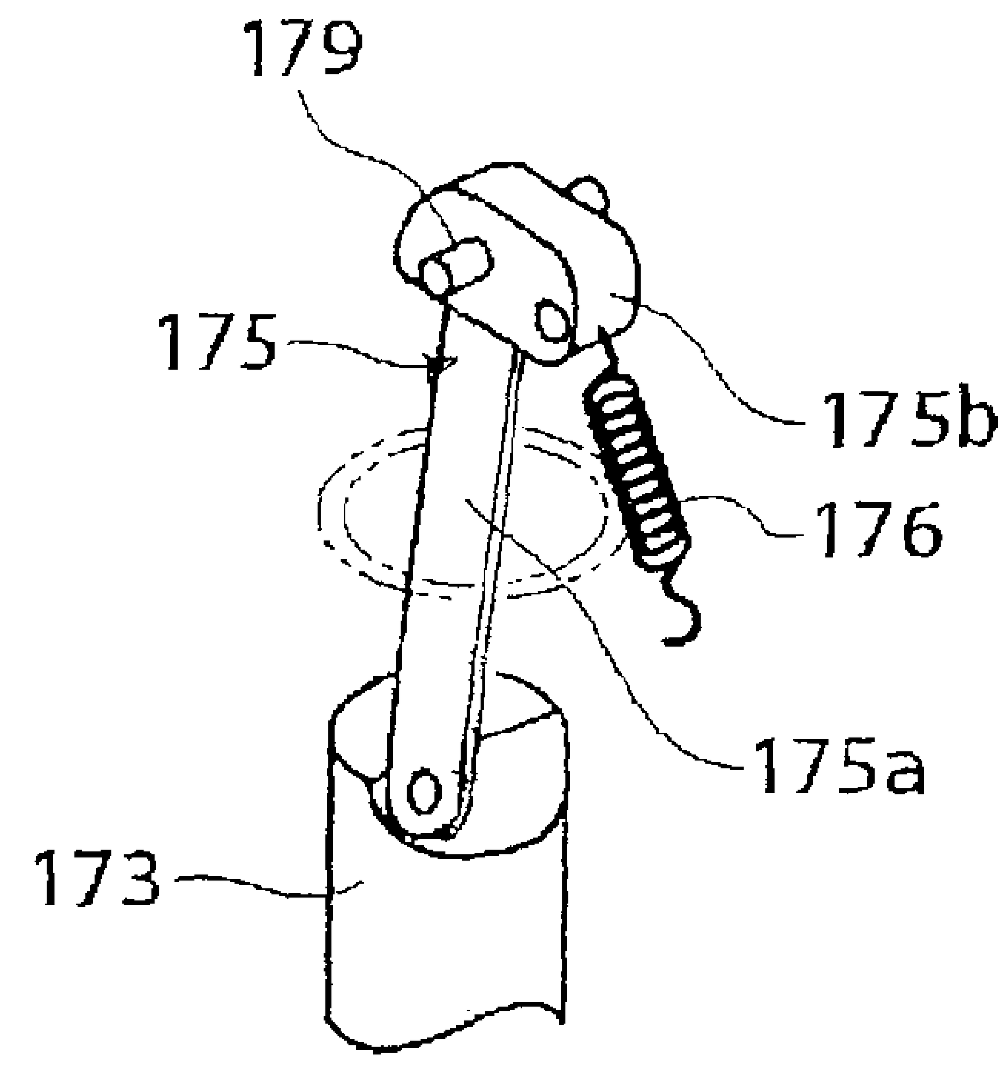


Fig. 15B

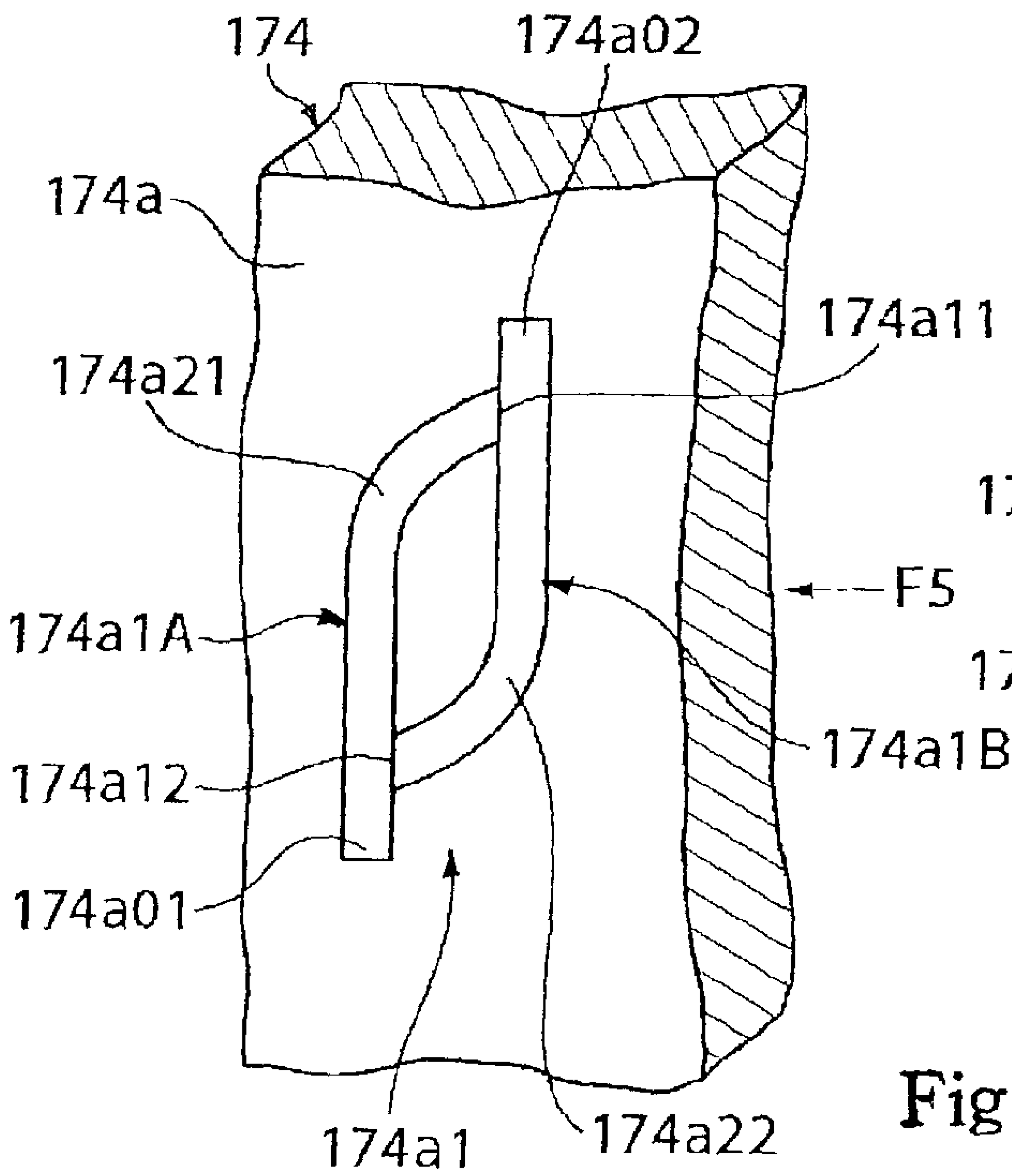


Fig. 15C

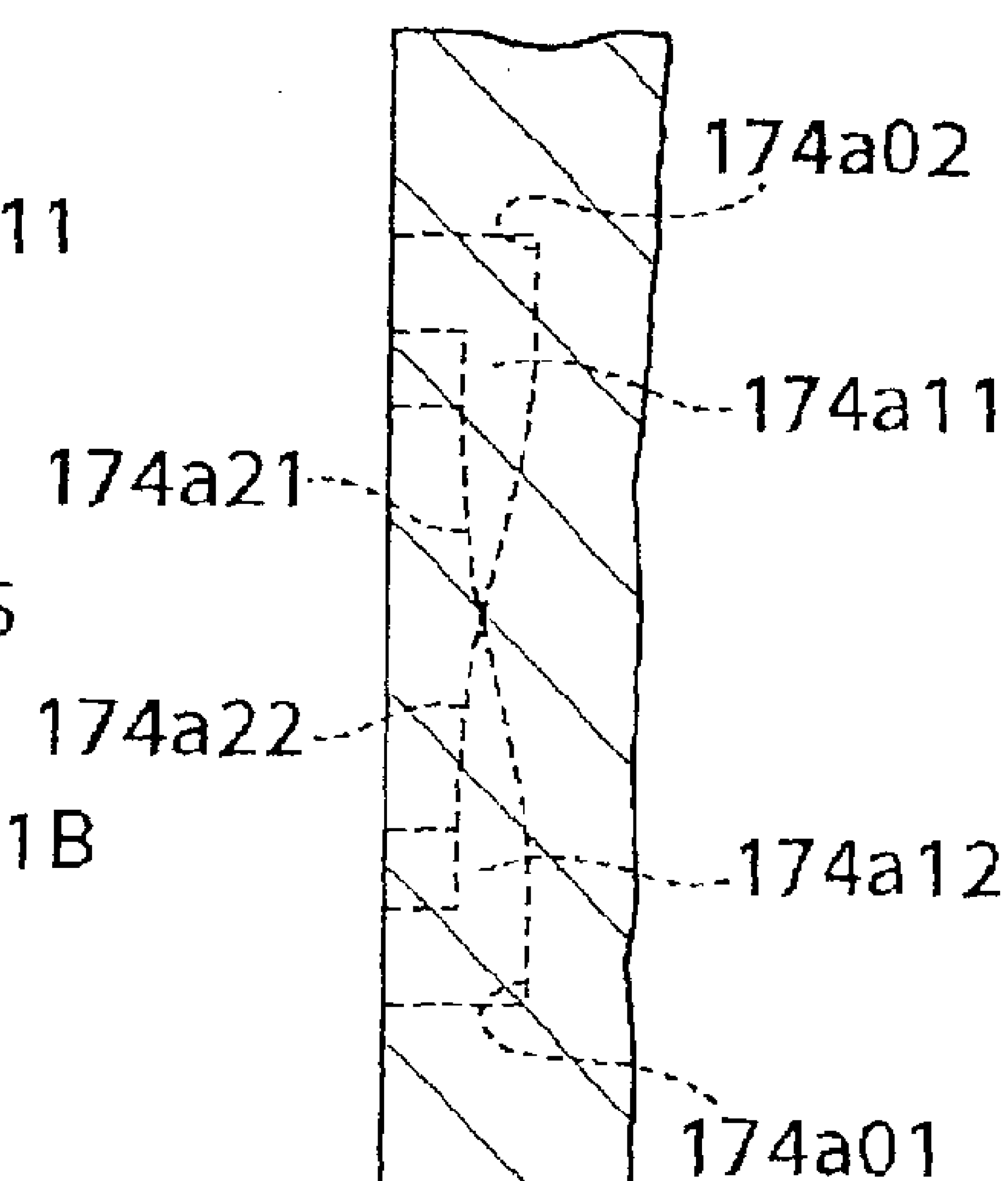


Fig. 15D

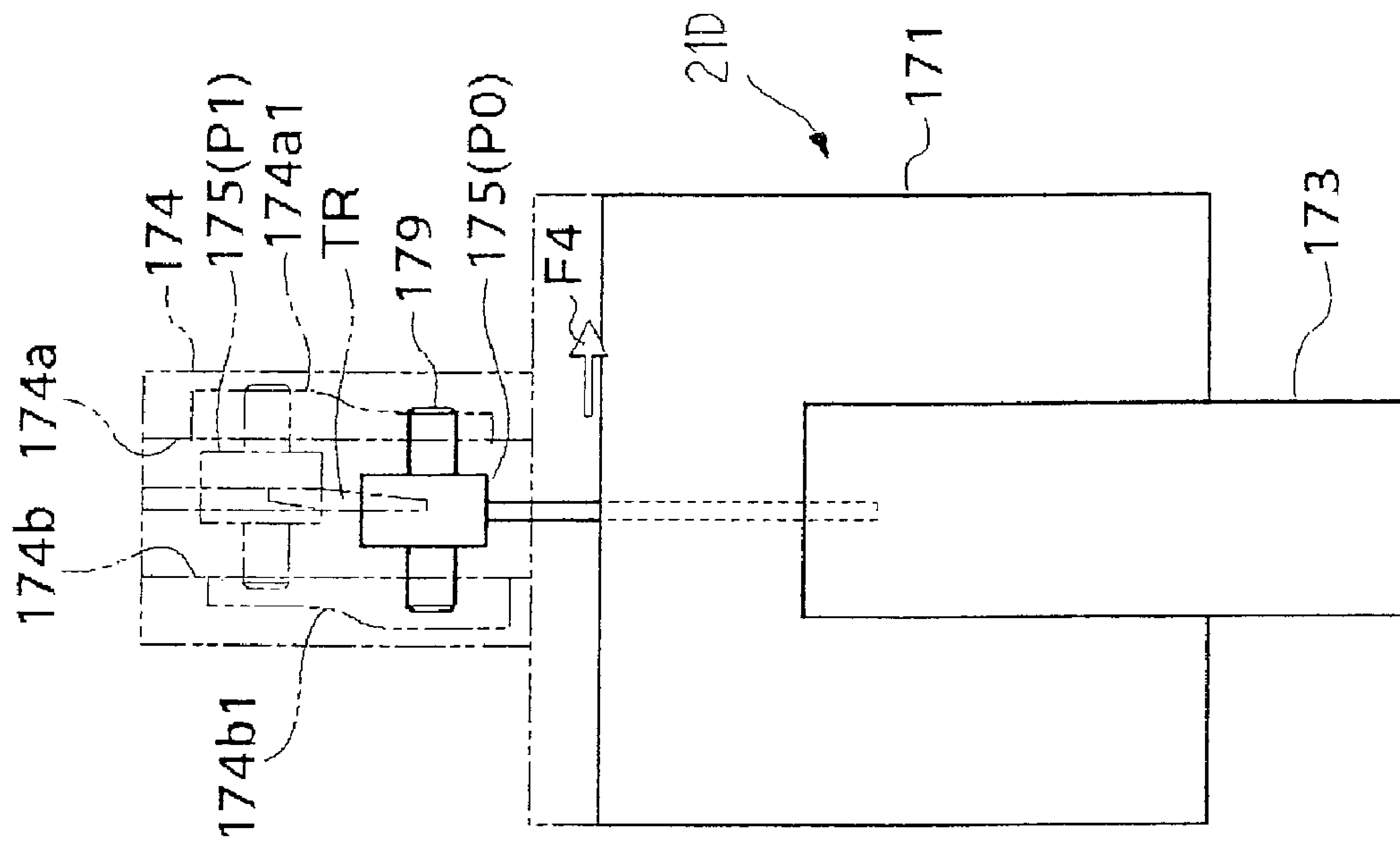


Fig. 15F

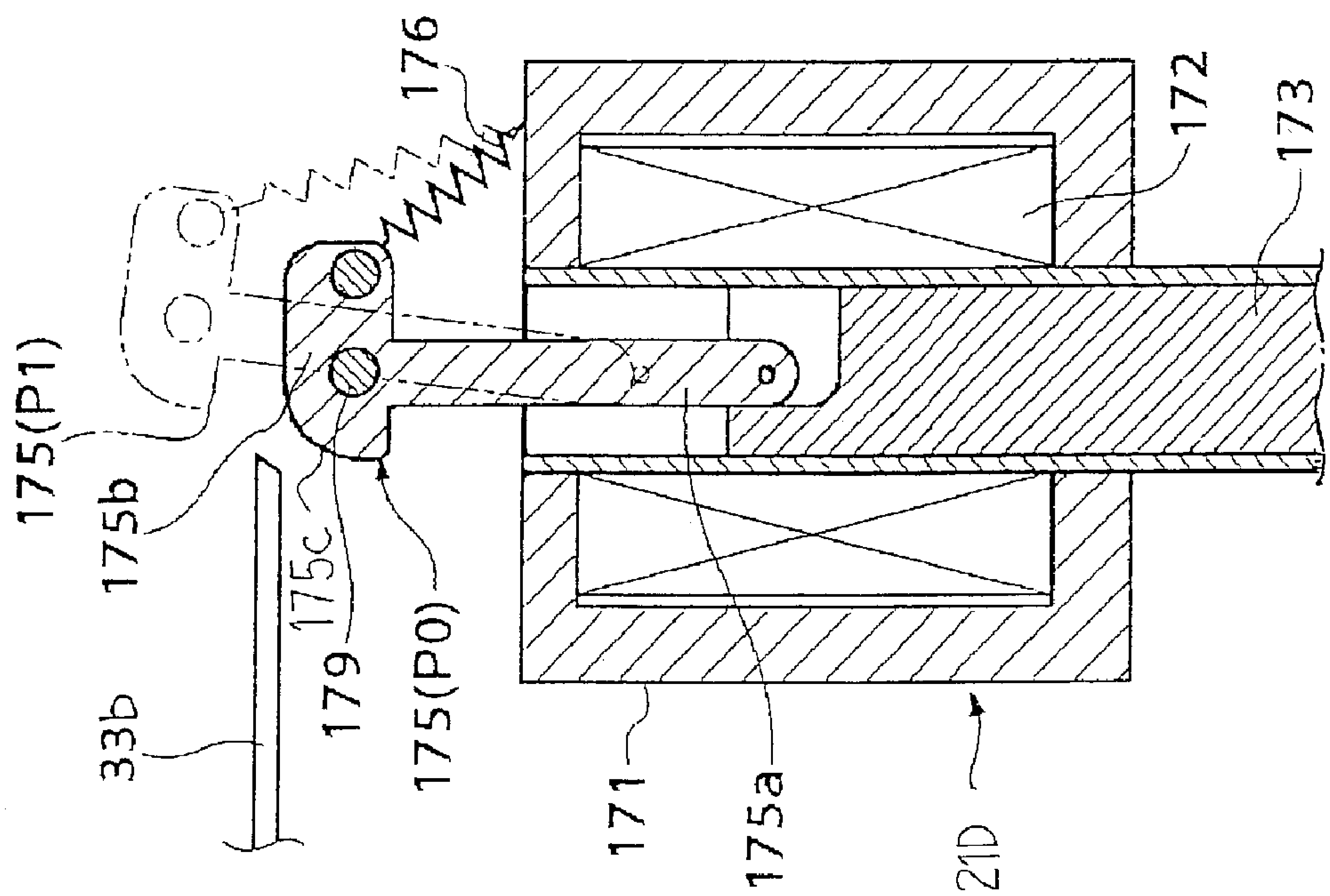


Fig. 15E

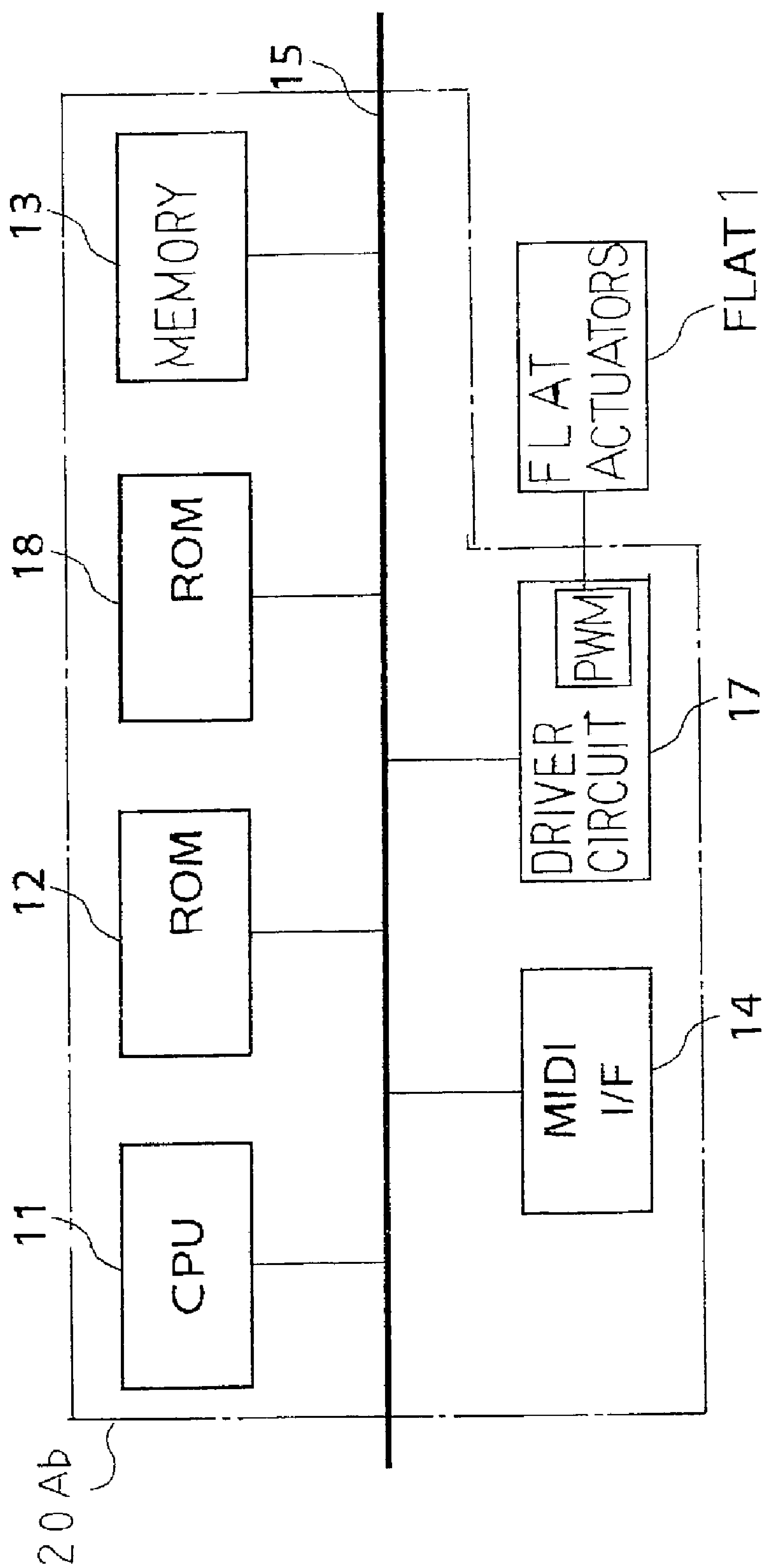
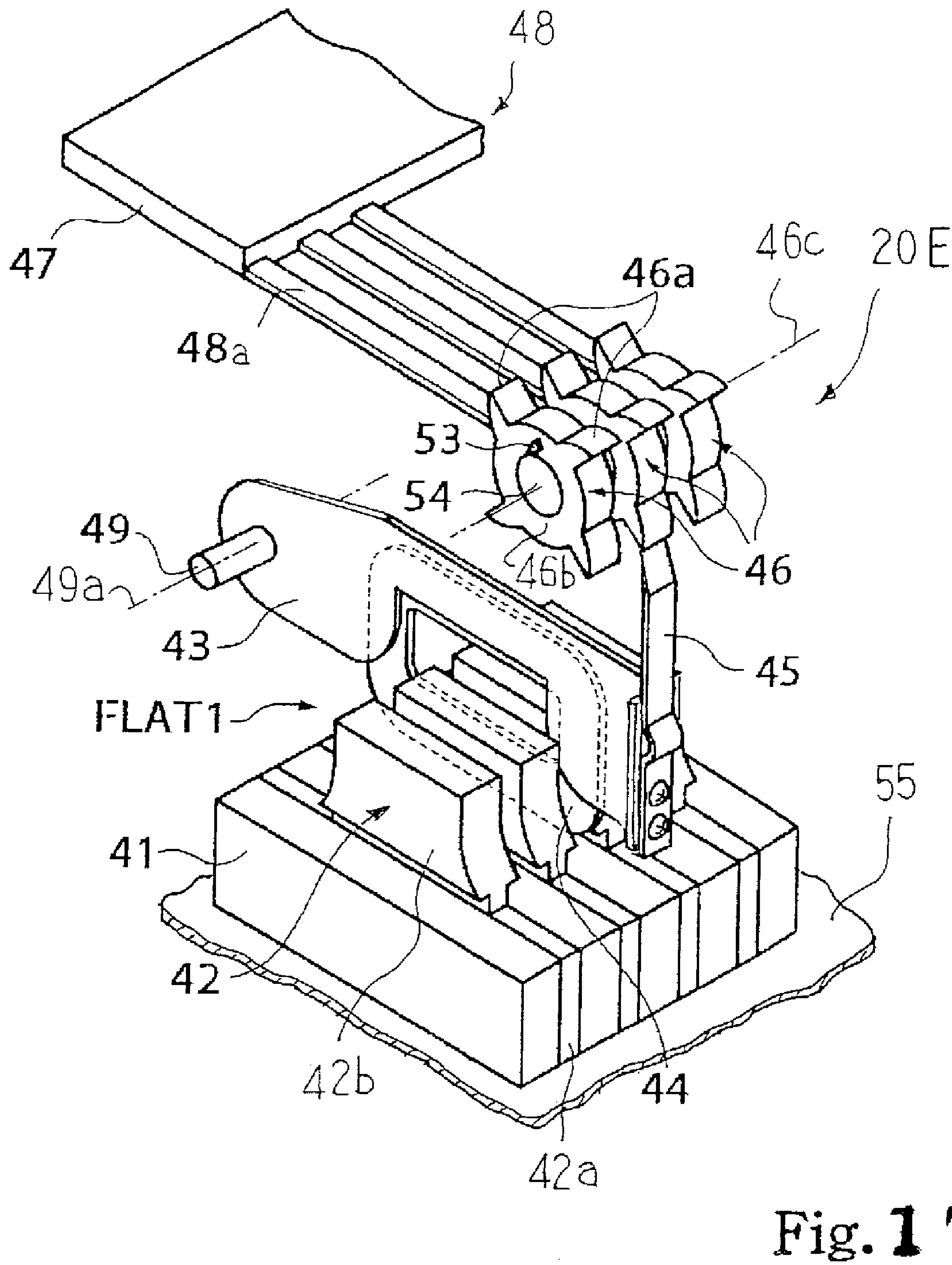

15
13
MEMORY
18
ROM
12
ROM
11
CPU
FLAT ACTUATORS
FLAT 1
DRIVER CIRCUIT
PWM
17
MIDI I/F
14
20 Ab

Fig. 16


48
47
48a
46a
46c
20E
53
54
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49a
46b
46
43
45
FLAT1
55
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42b
44
42a

Fig. 17

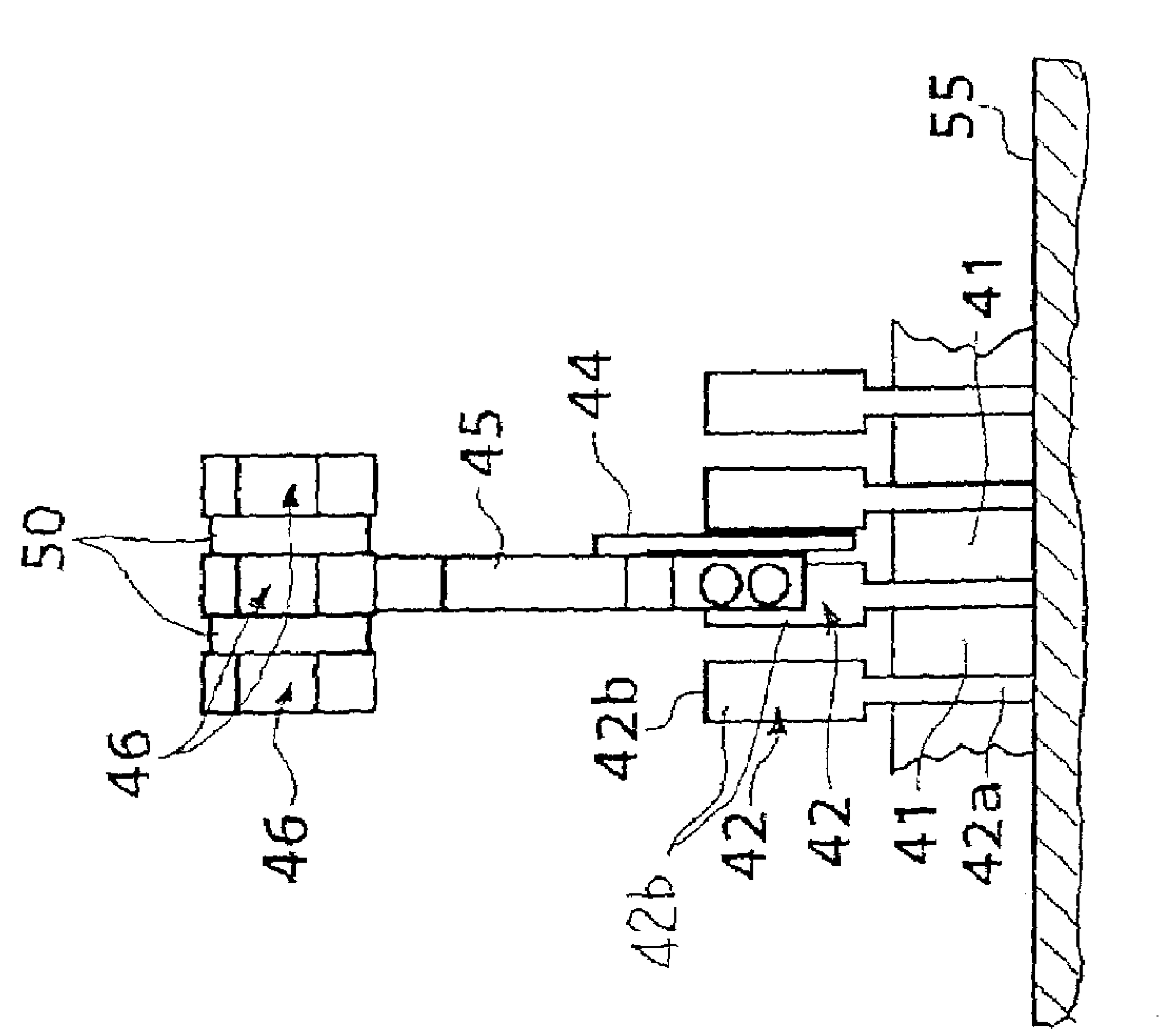


Fig. 18B

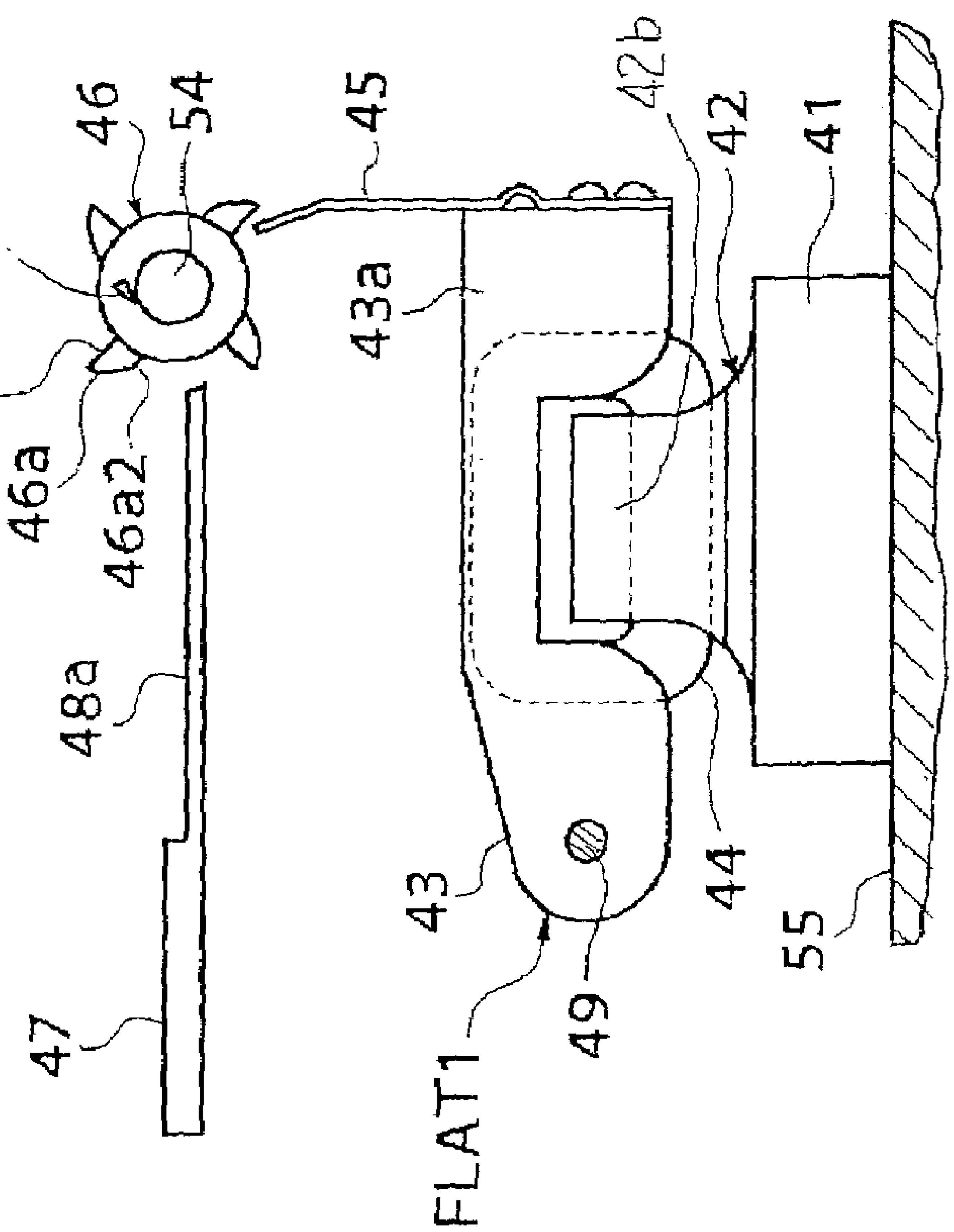
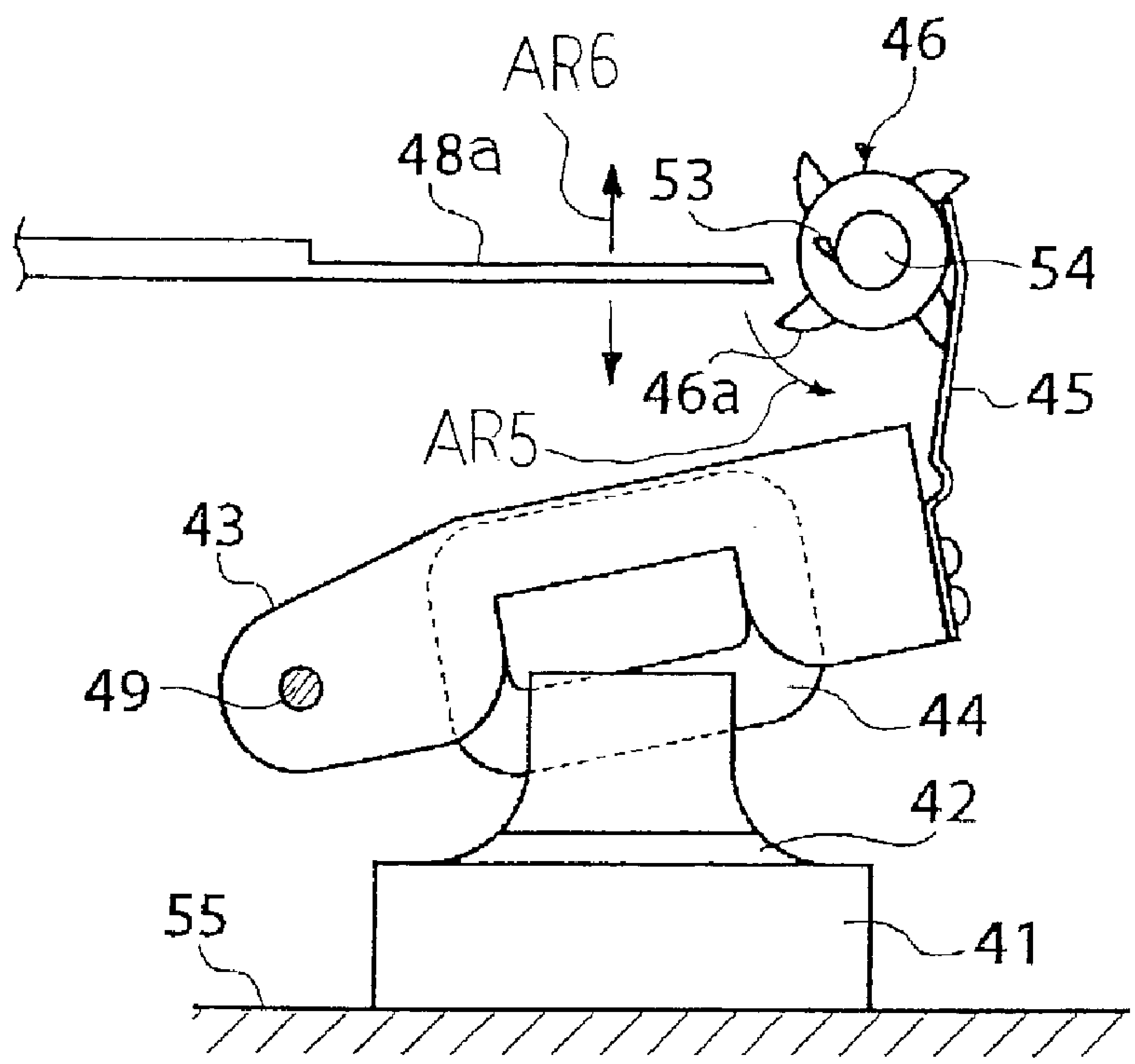


Fig. 18A



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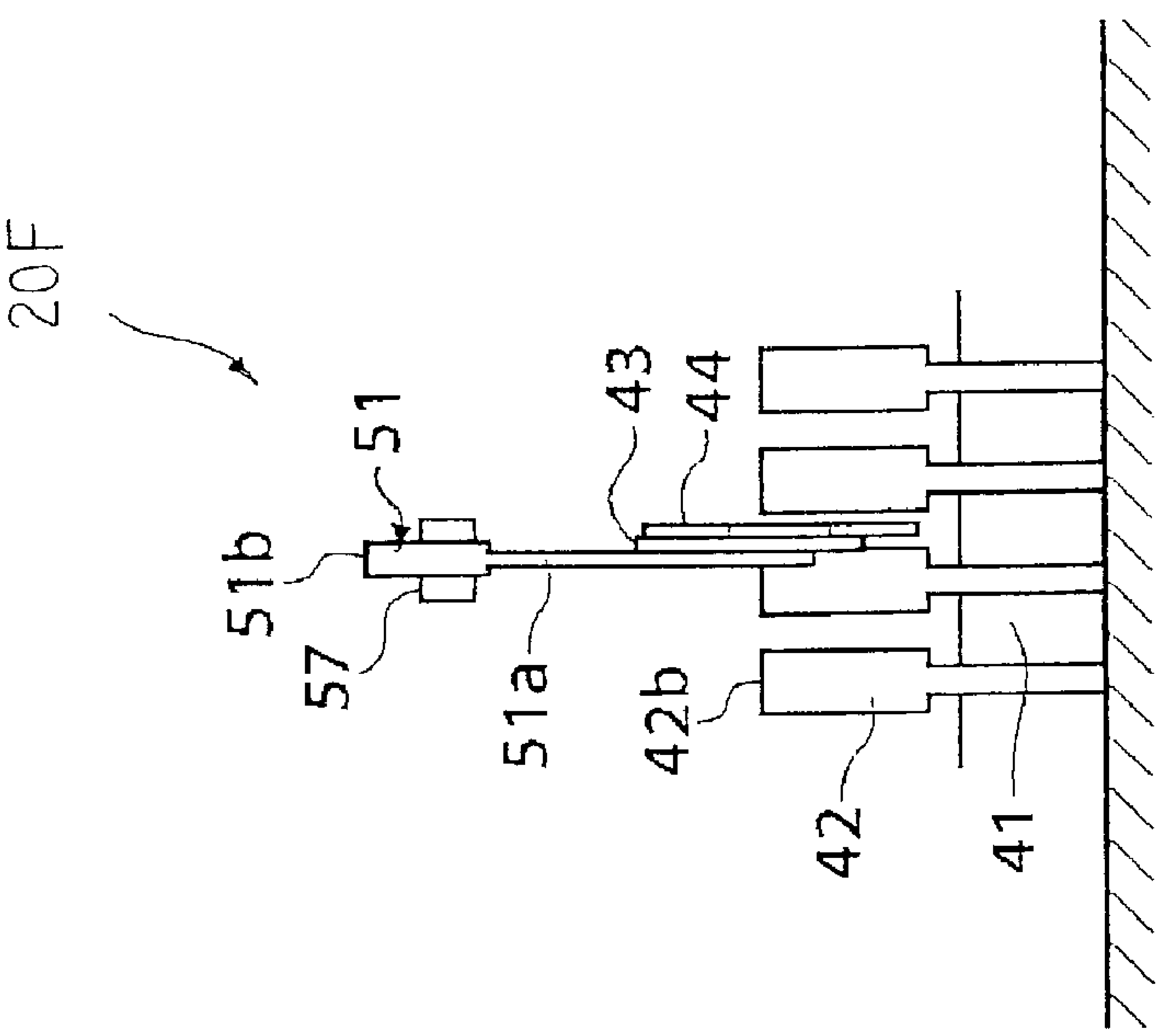


Fig. 20B

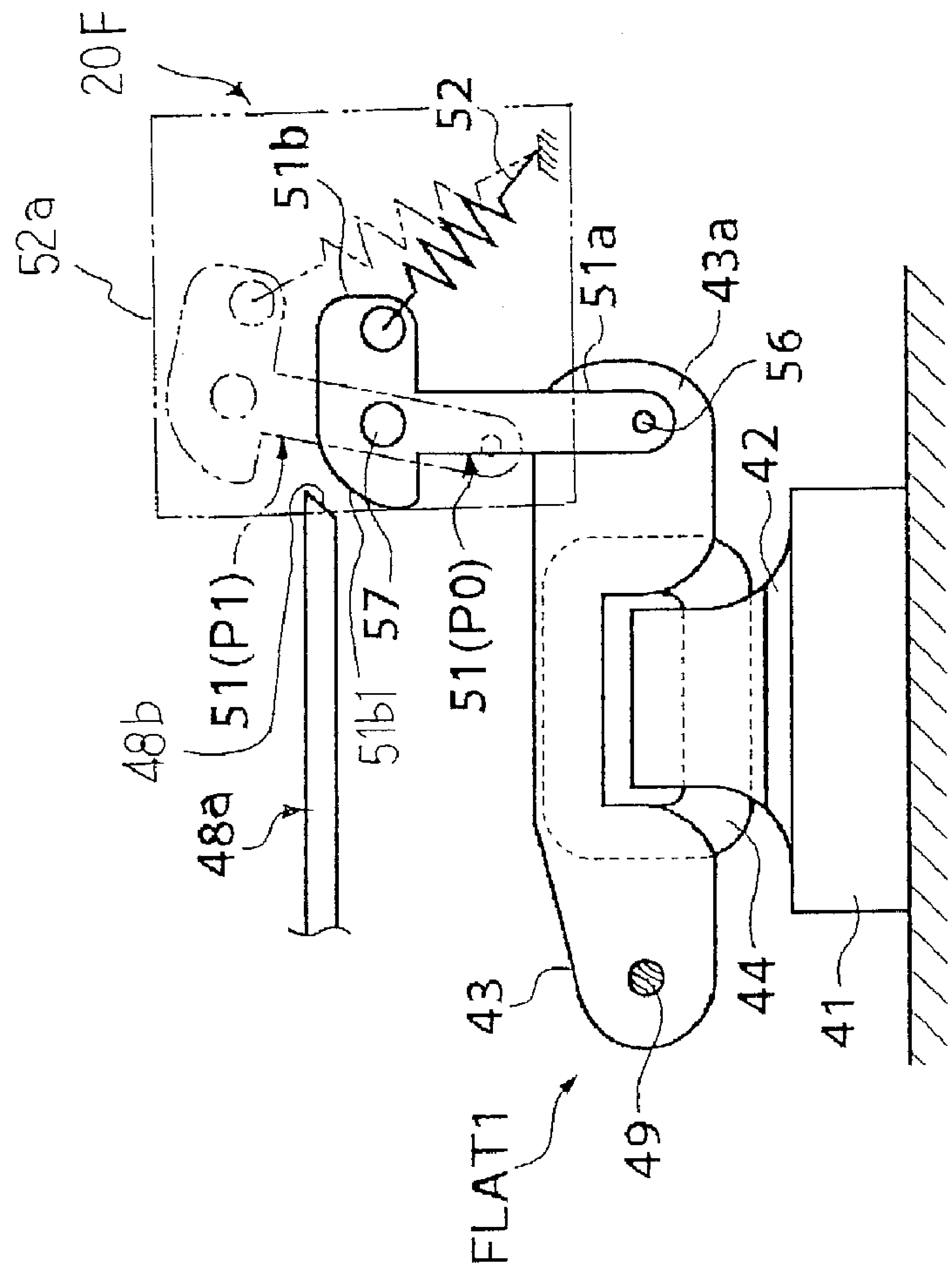


Fig. 20A

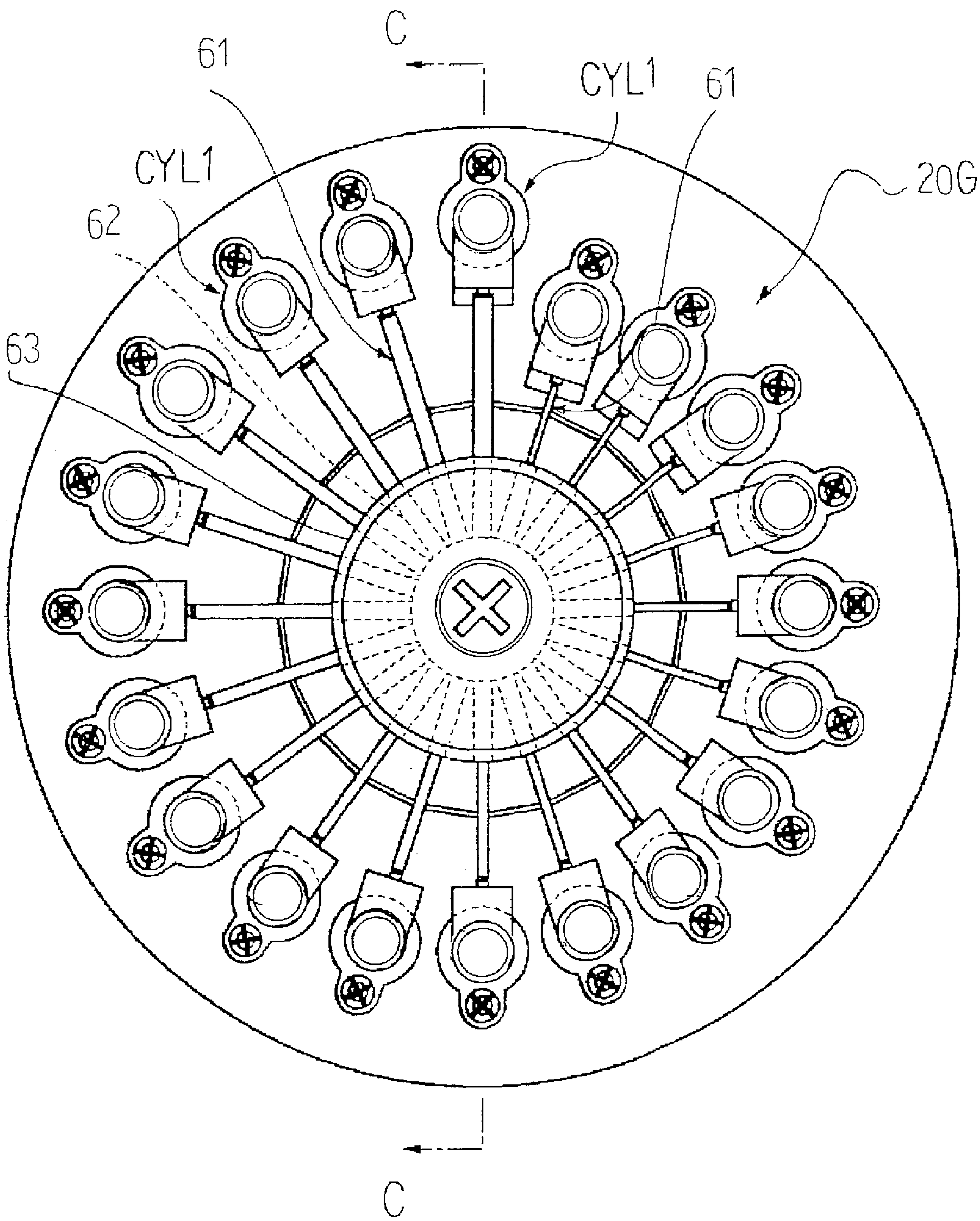


Fig. 21

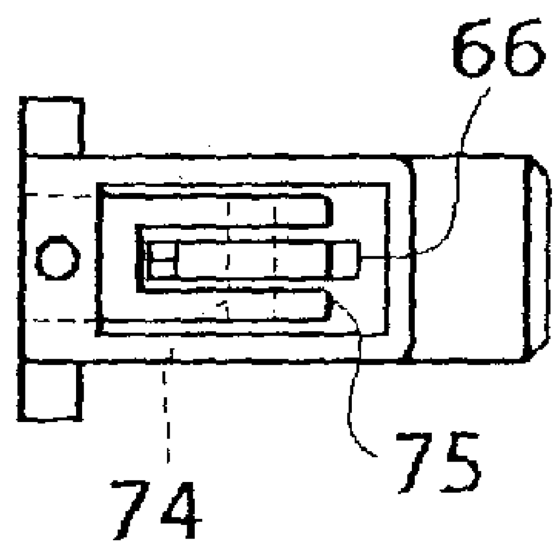


Fig. 22 C

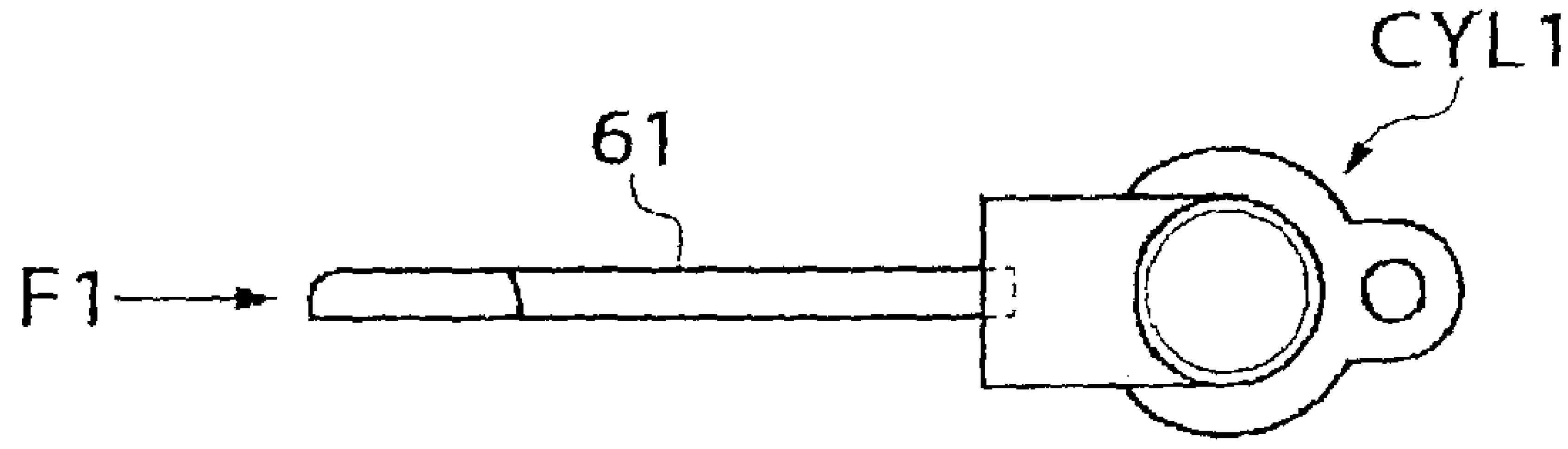
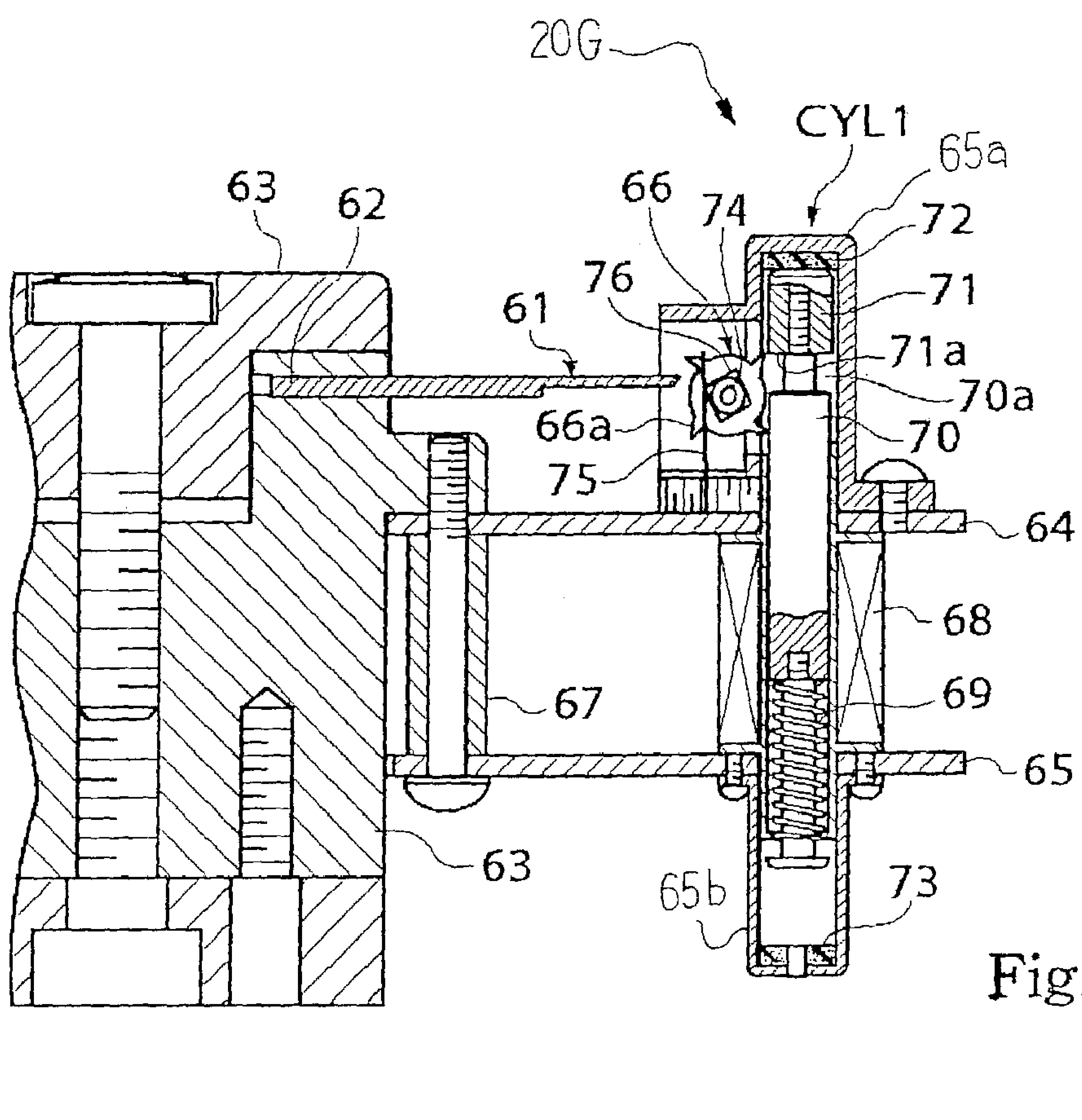


Fig. 22 B



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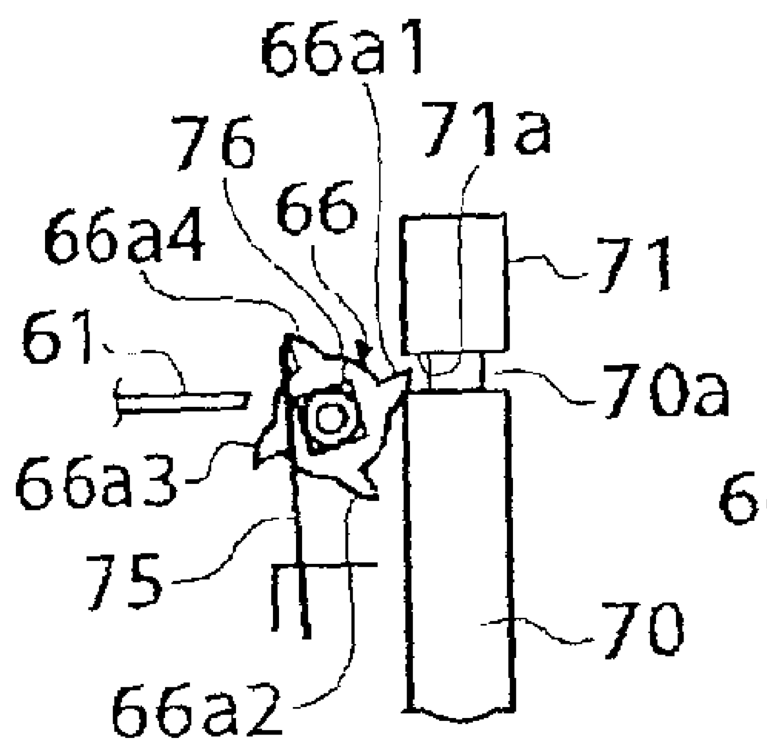

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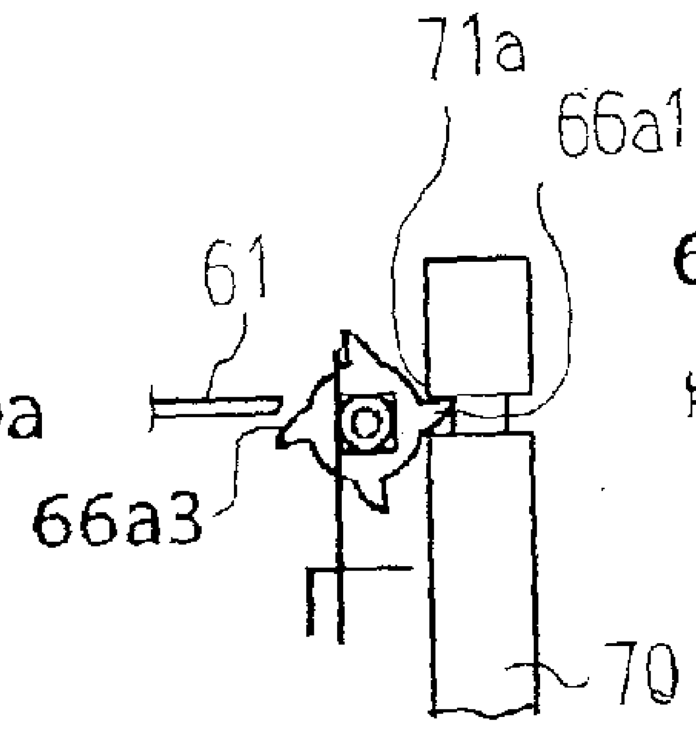
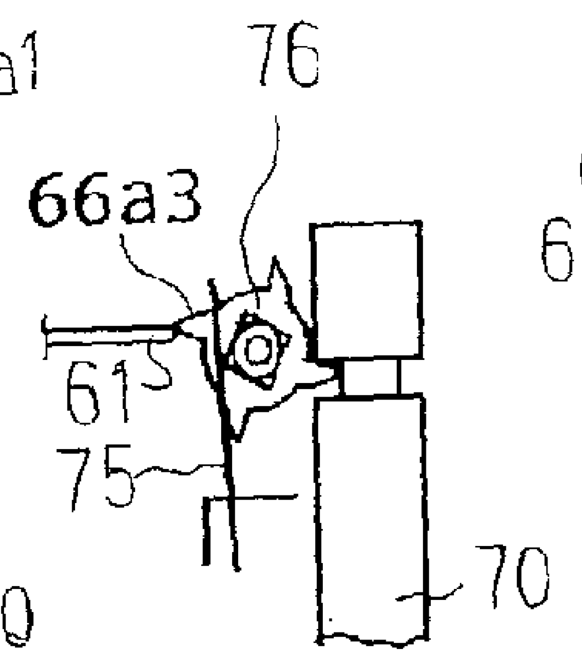


Fig.23B



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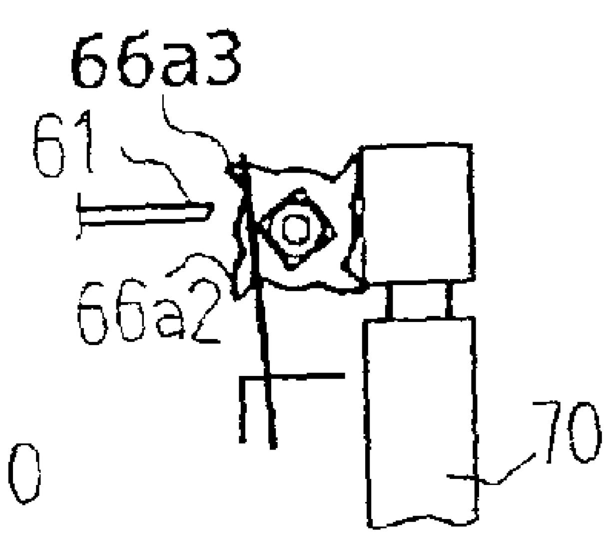

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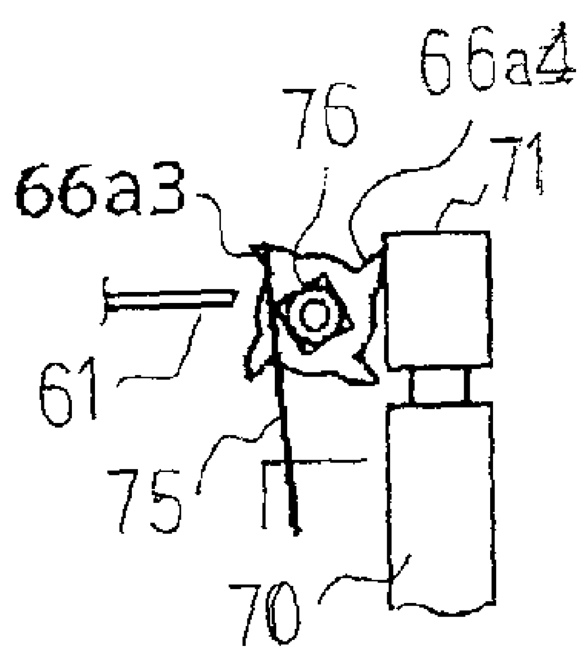

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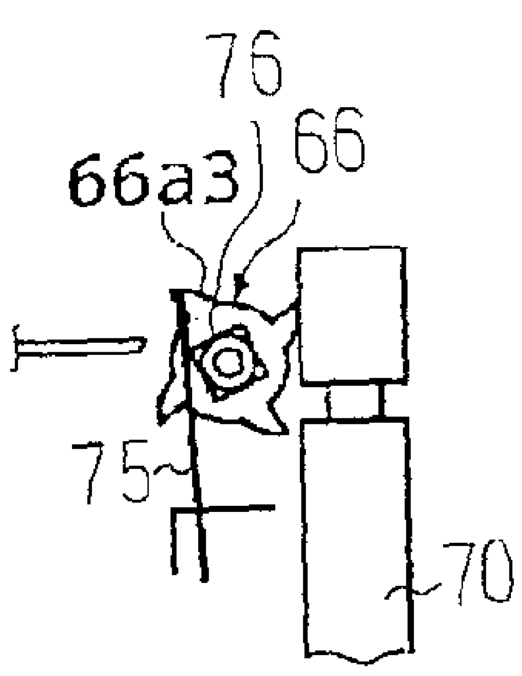
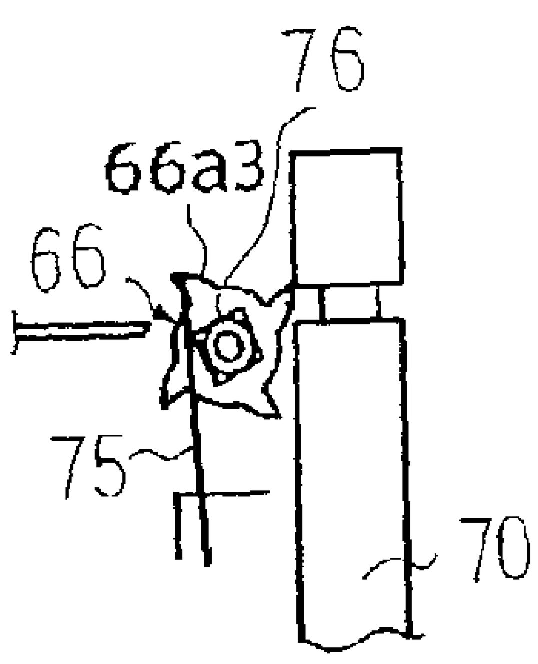


Fig.23F



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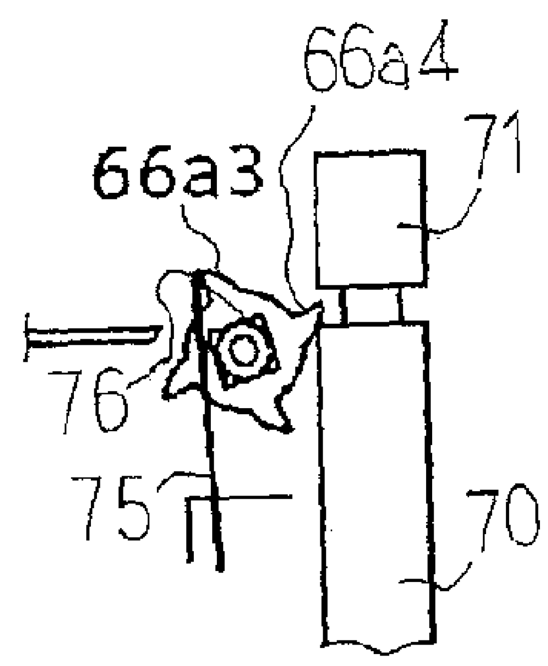

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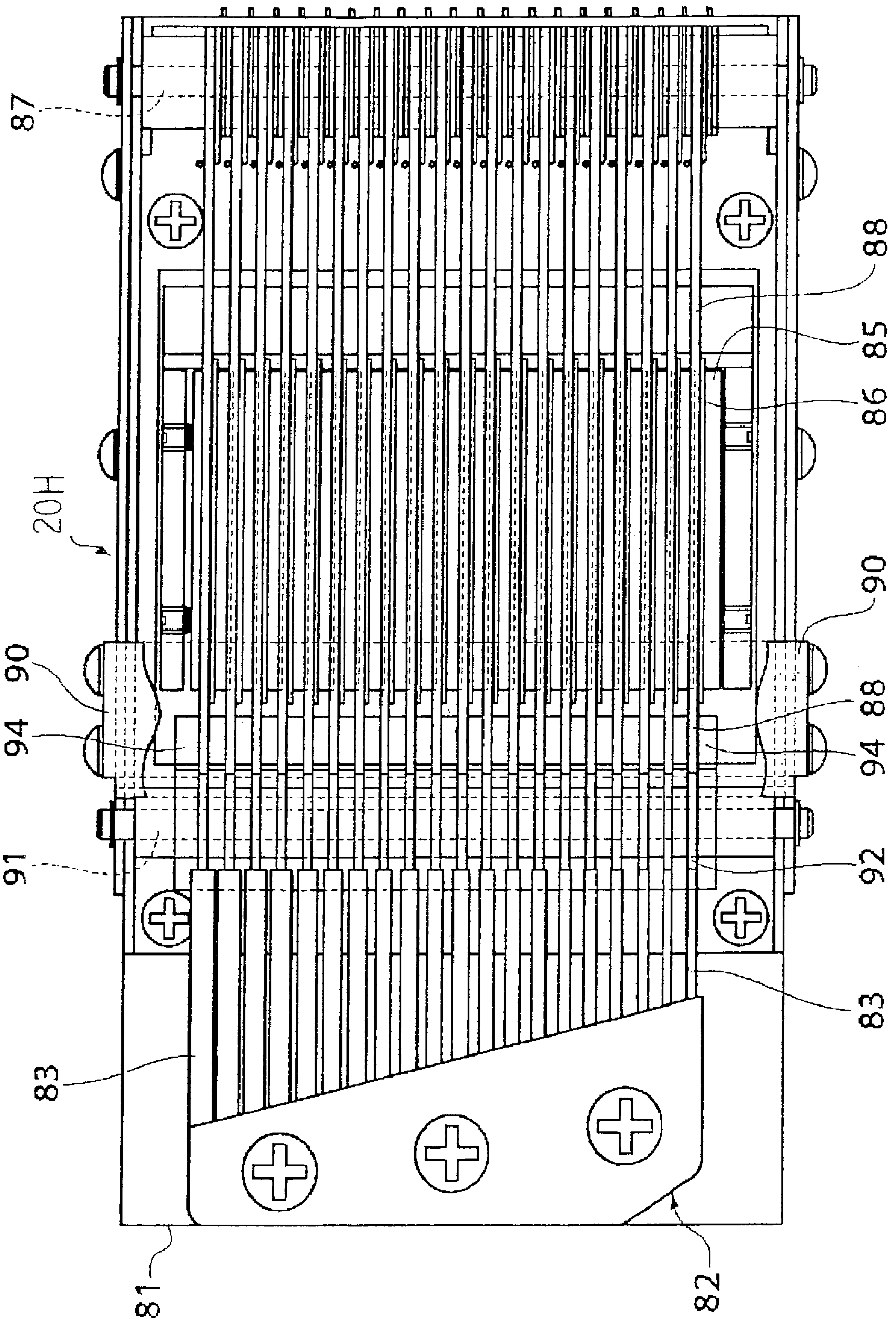

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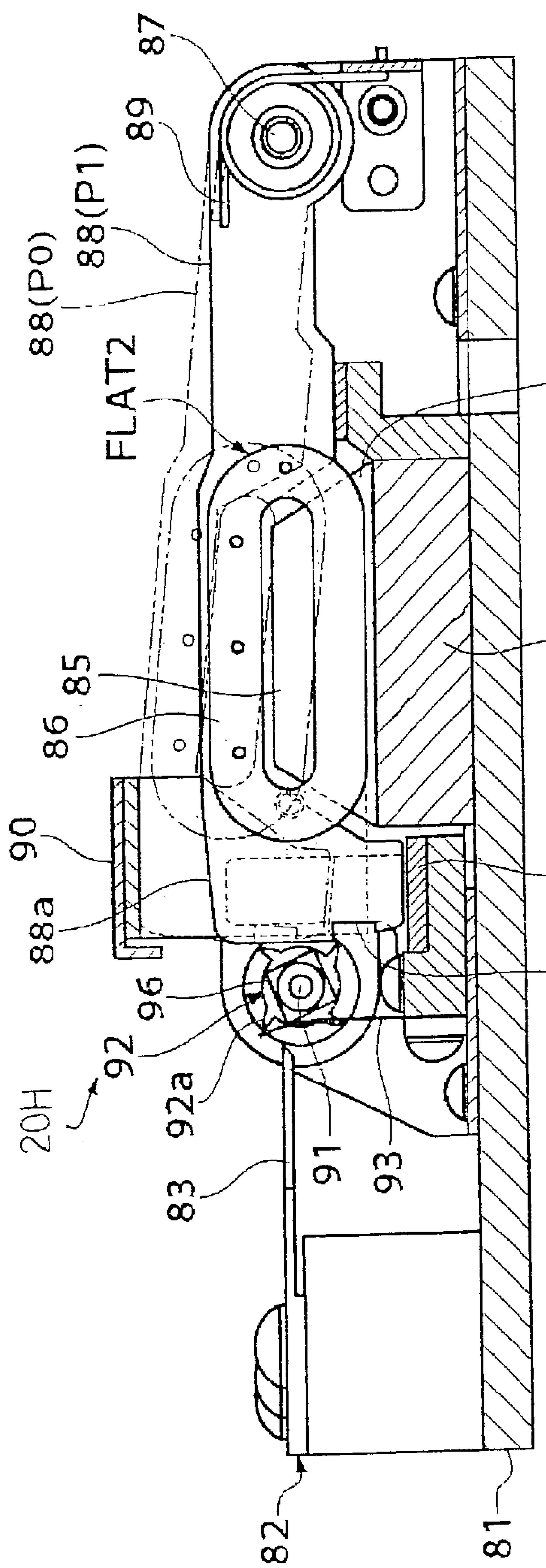


Fig. 25A

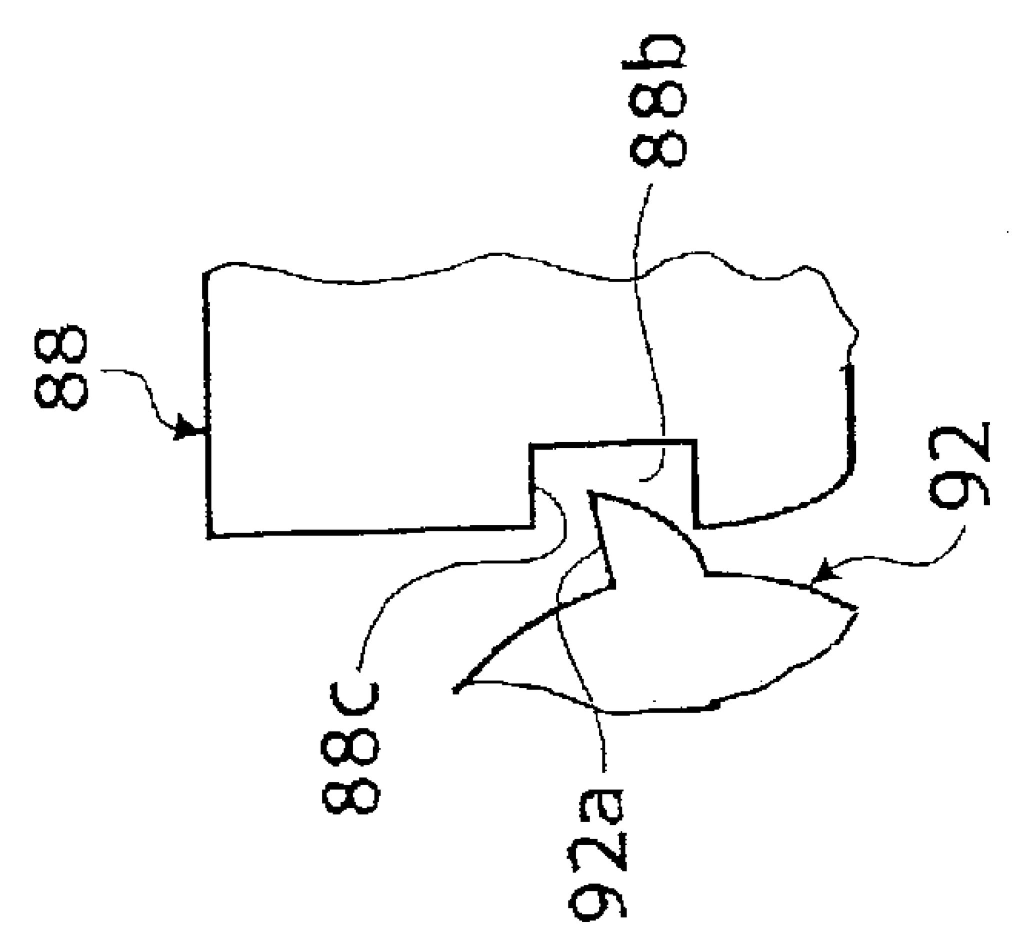
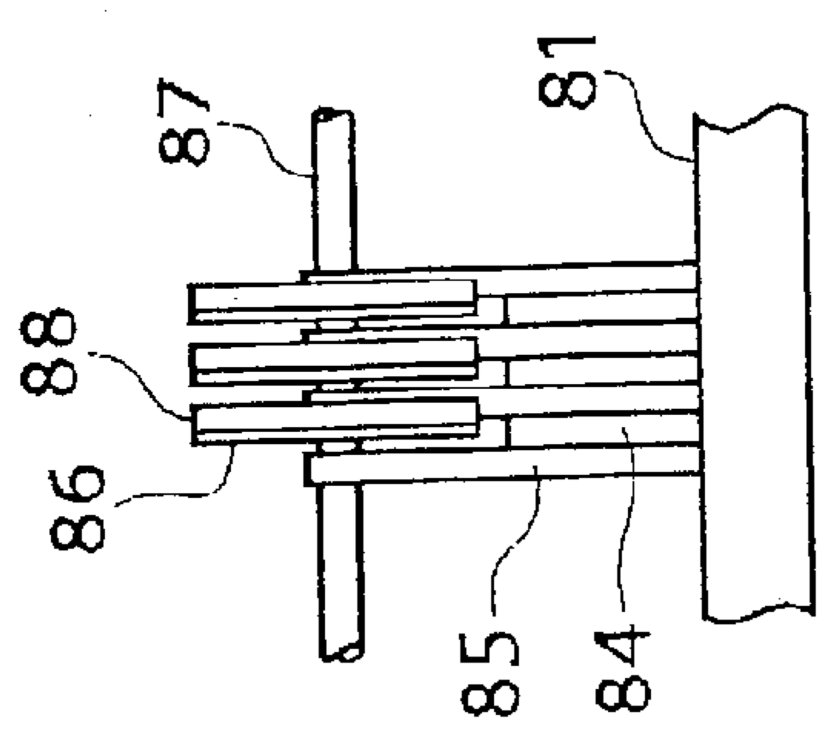


Fig. 25C



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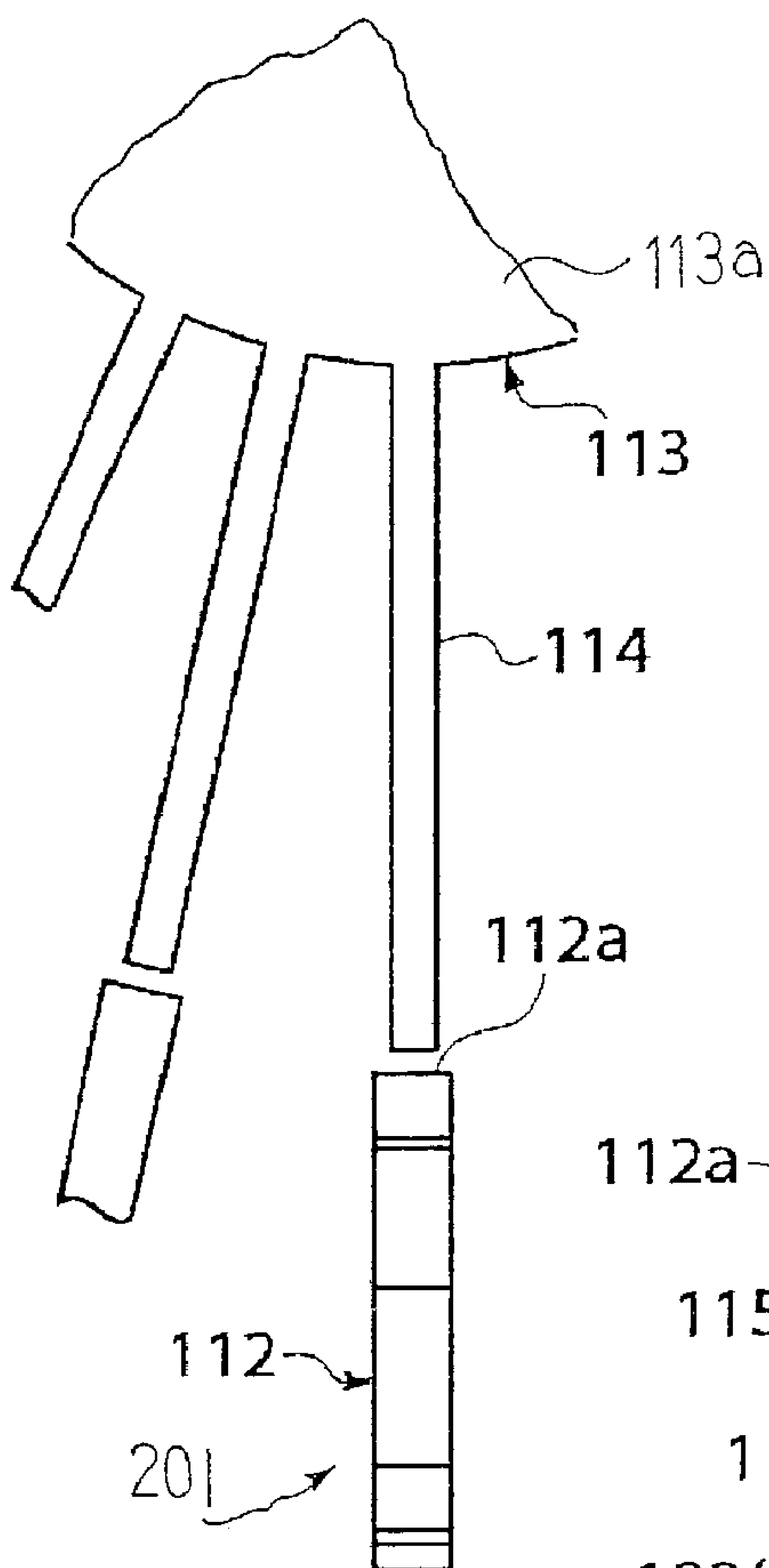


Fig. 26 A

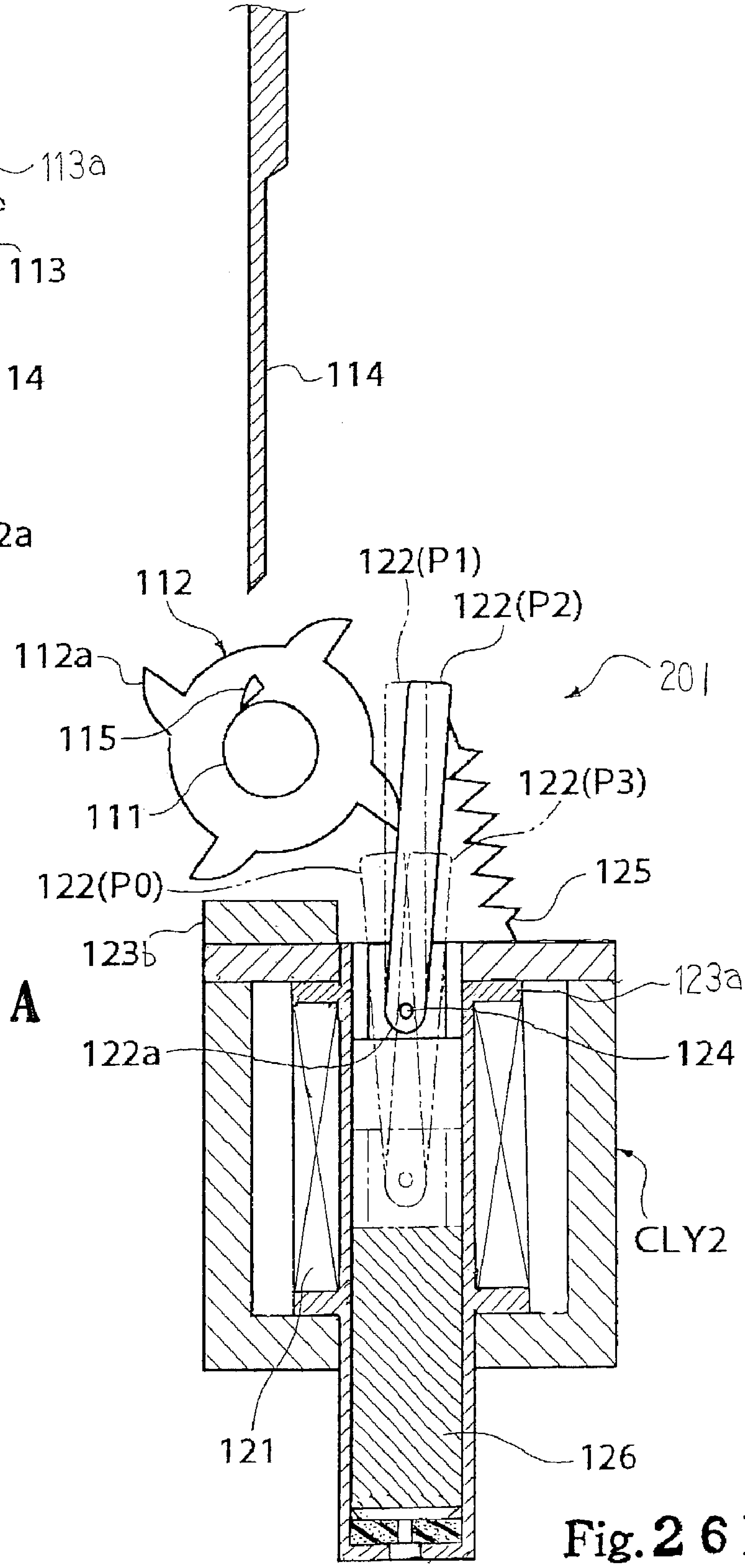


Fig. 26 B

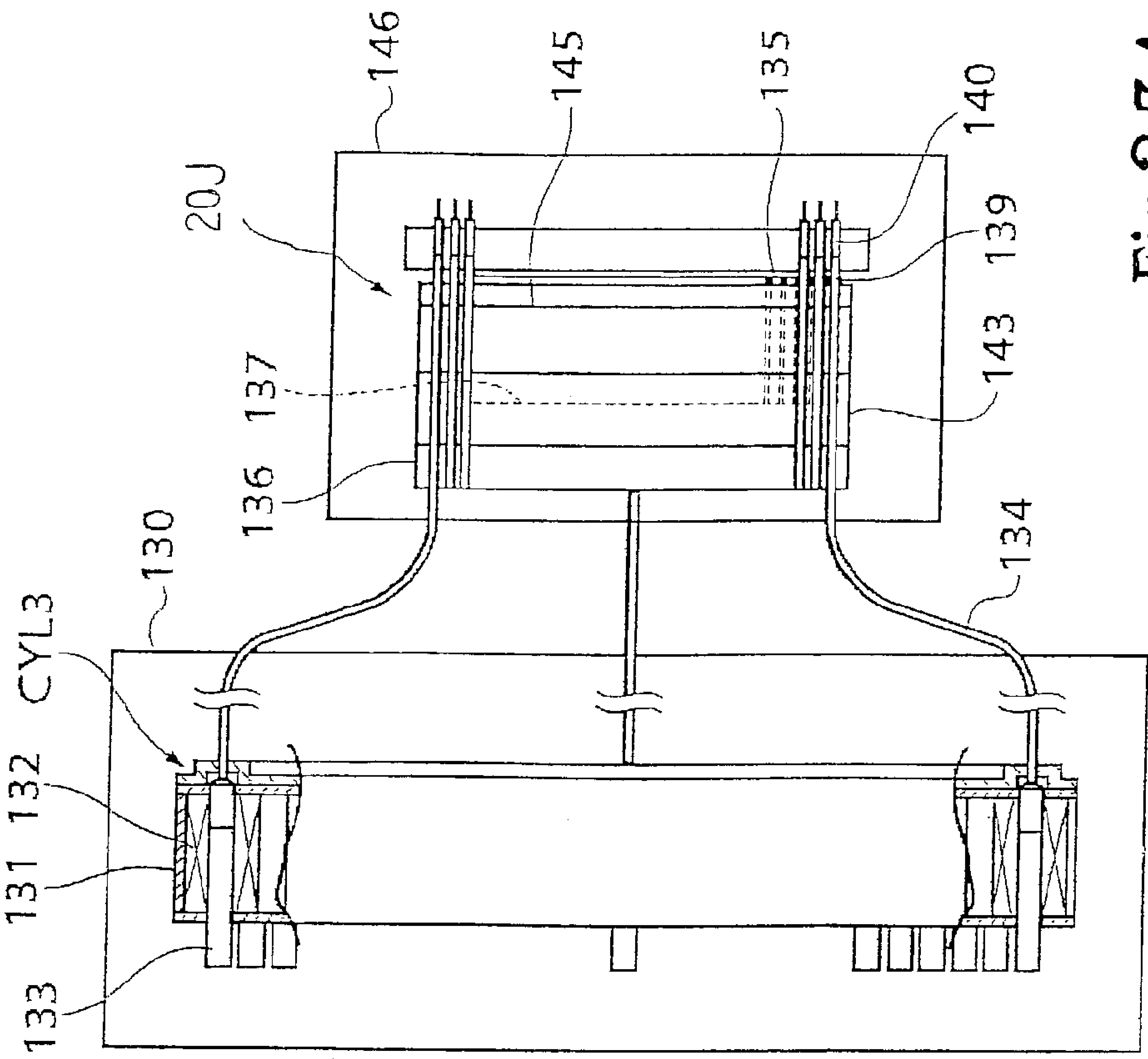


Fig.27A

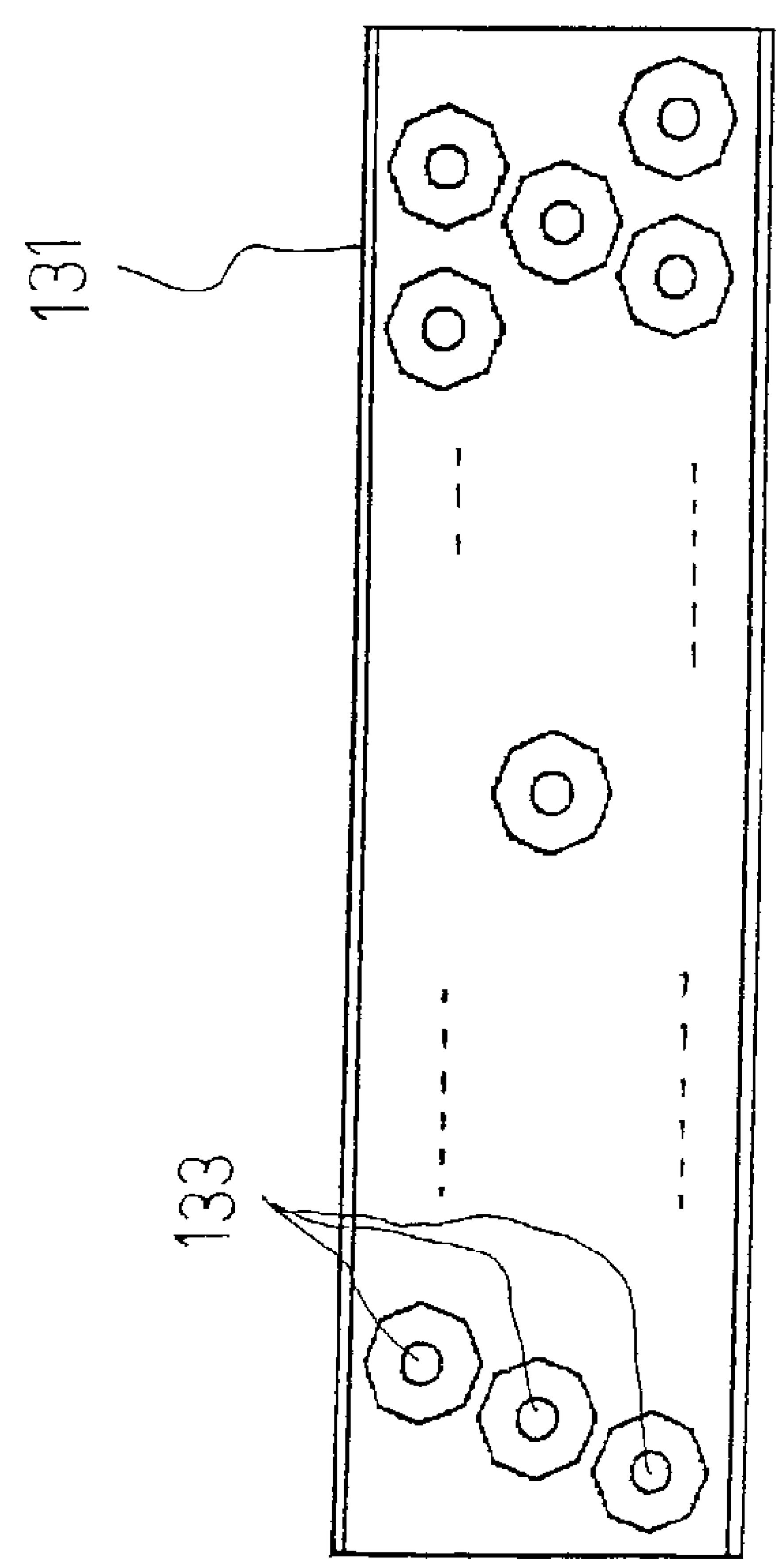
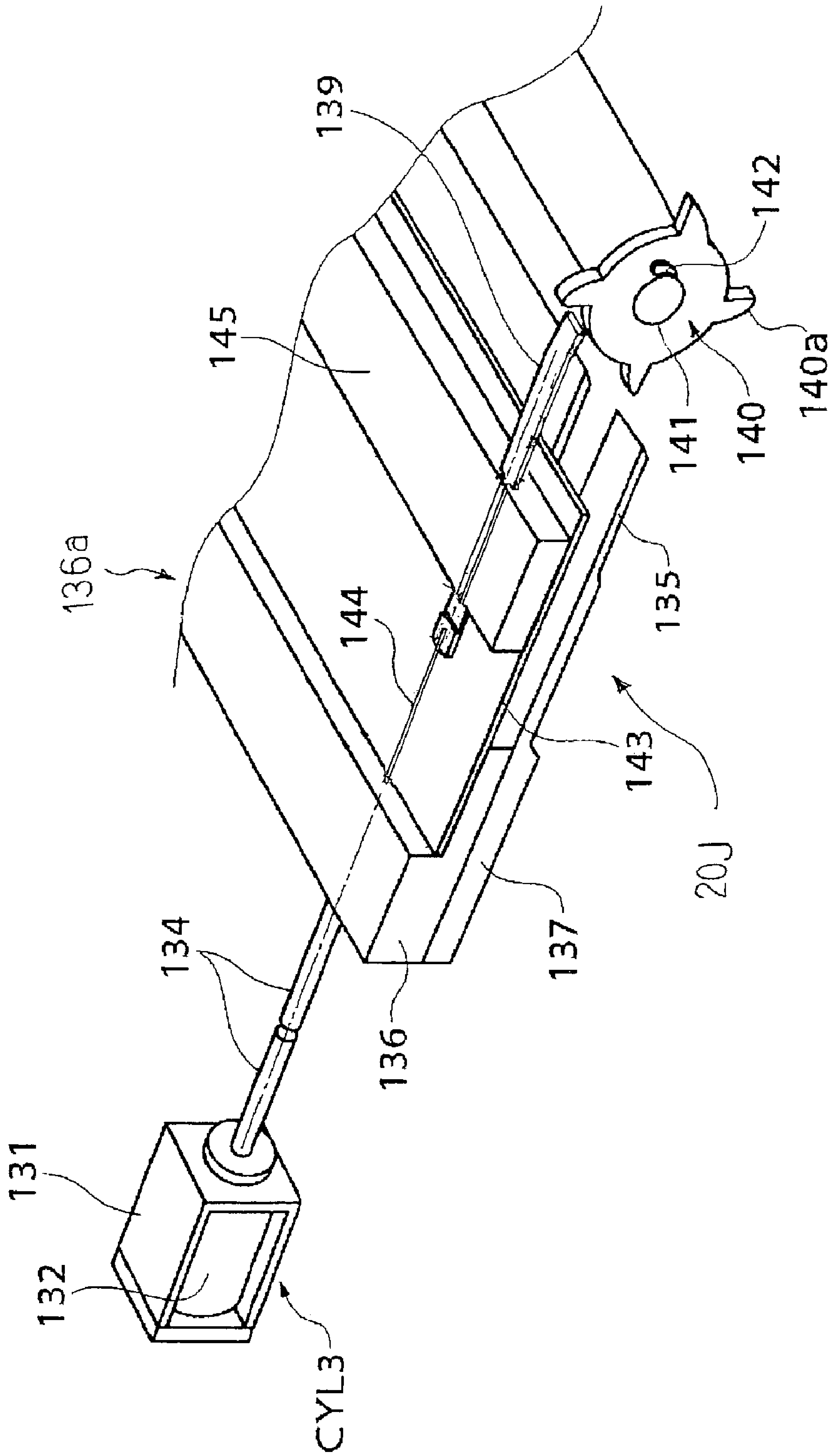


Fig.27B



139
142
145
141
140
140a
136a
144
135
143
20J
134
137
136
131
132
CYL3

Fig. 28

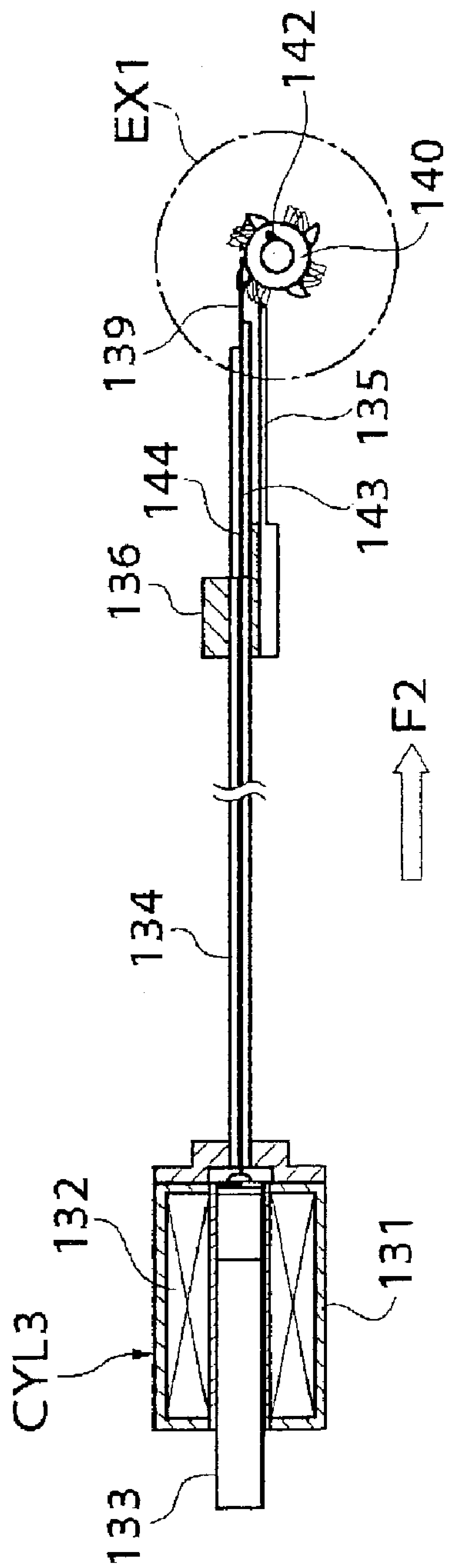


Fig. 29A

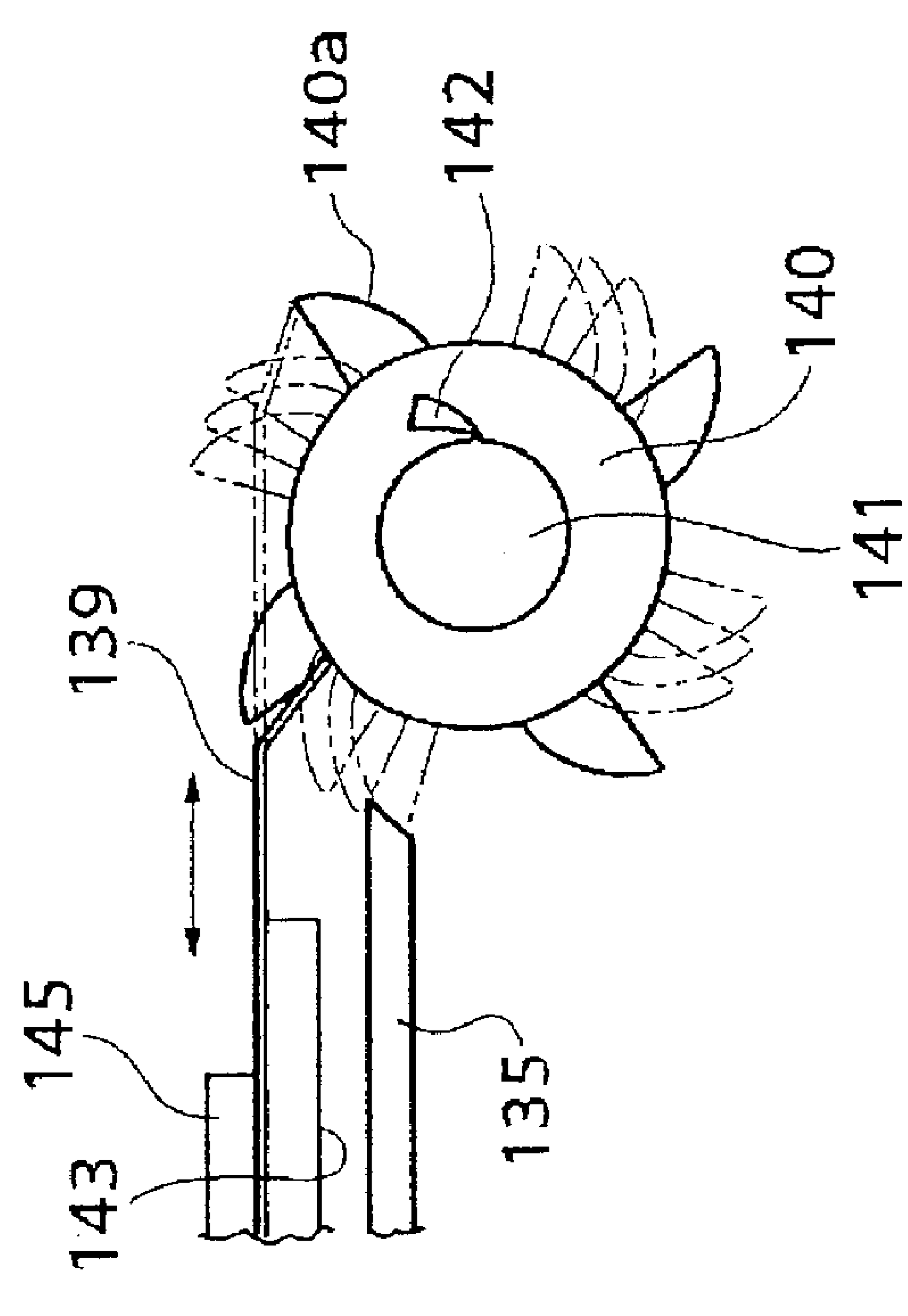


Fig. 29B

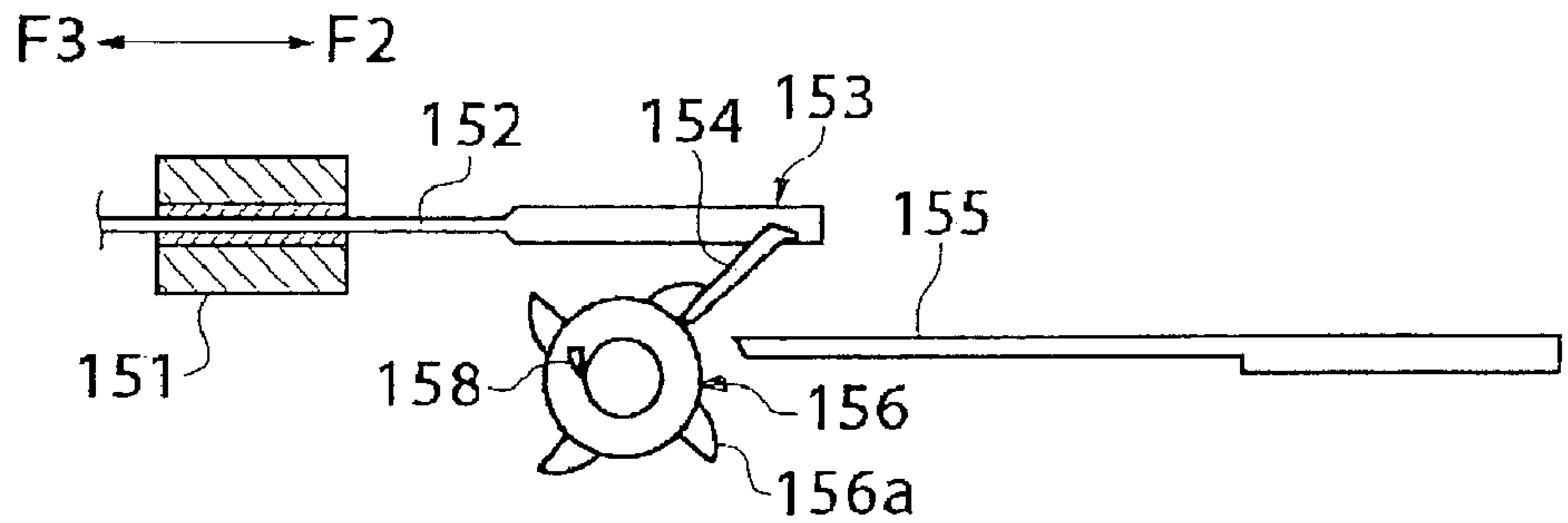


Fig. 30 A

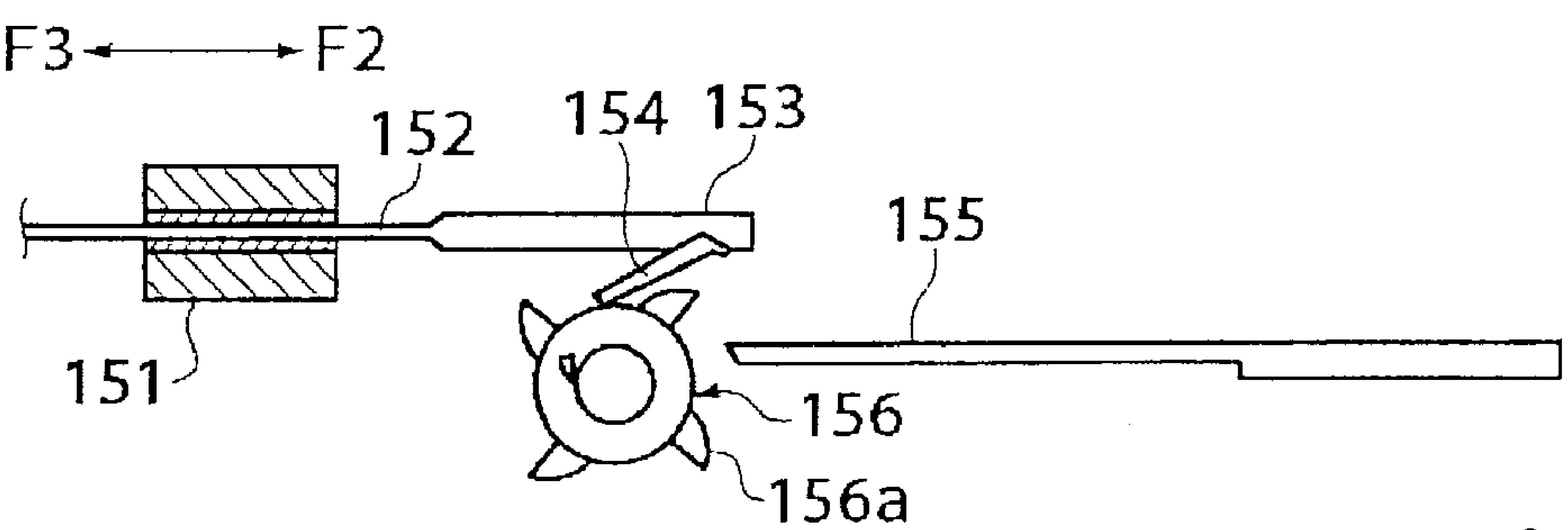


Fig. 30 B

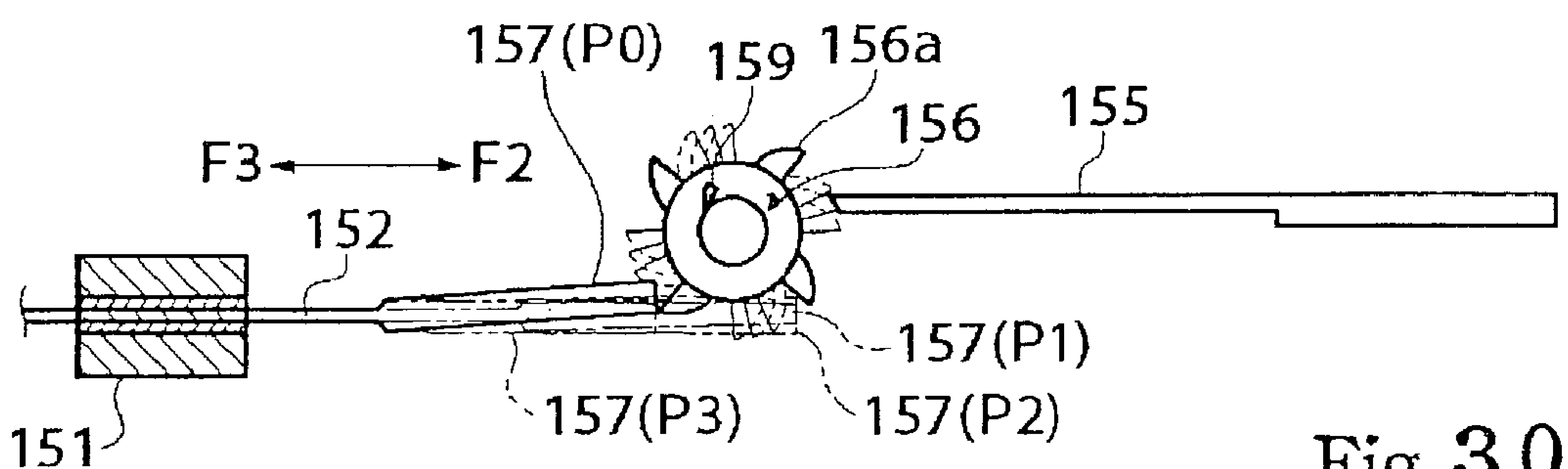


Fig. 30 C

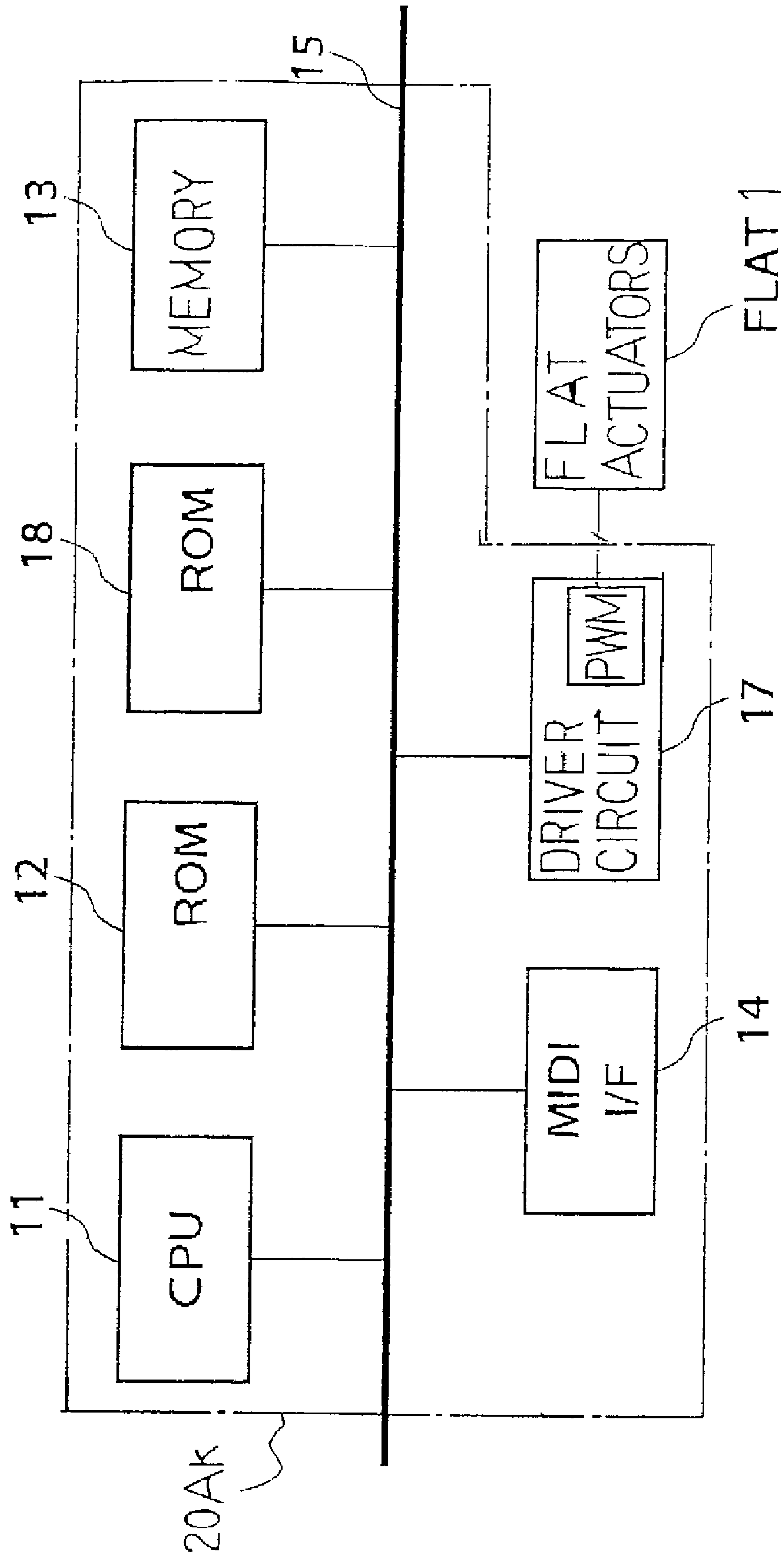
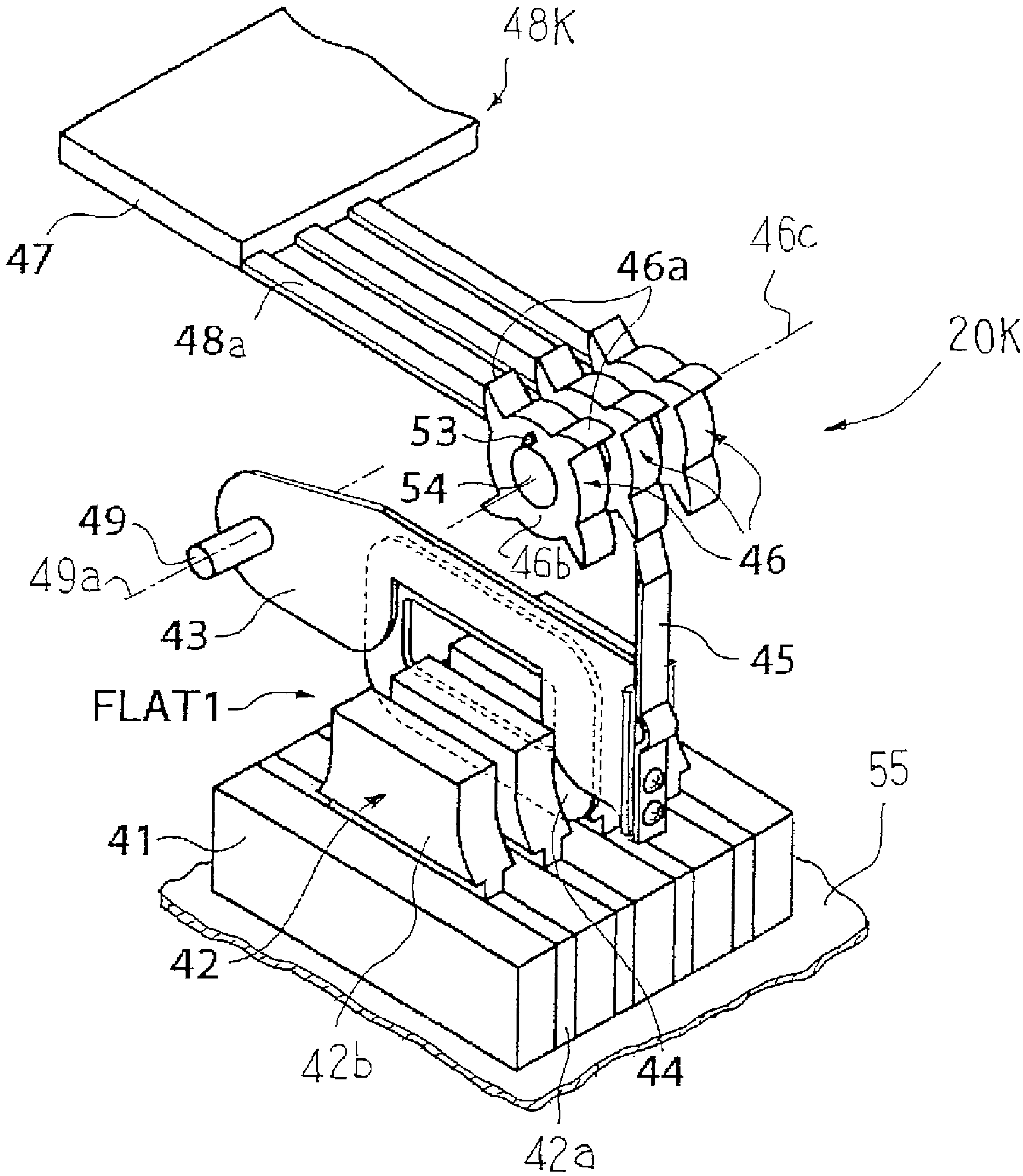

15
13
MEMORY
18
ROM
12
ROM
11
CPU
FLAT ACTUATORS
FLAT 1
DRIVER CIRCUIT
PWM
17
MIDI I/F
14
20Ak

Fig. 31


48K
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46c
46a
48a
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49a
46b
46
43
45
FLAT1
55
41
42
42b
44
42a

Fig. 32

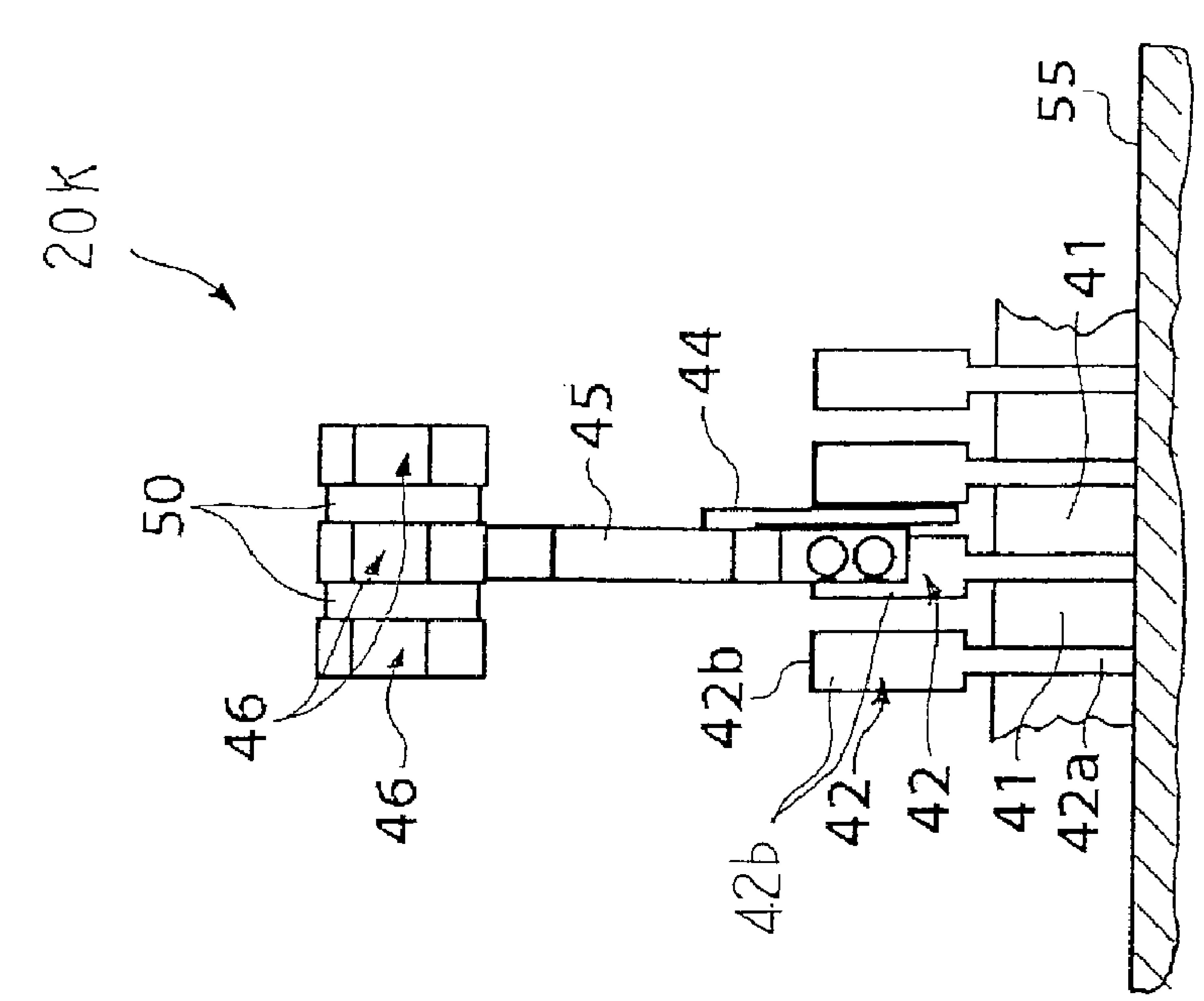


Fig. 33 B

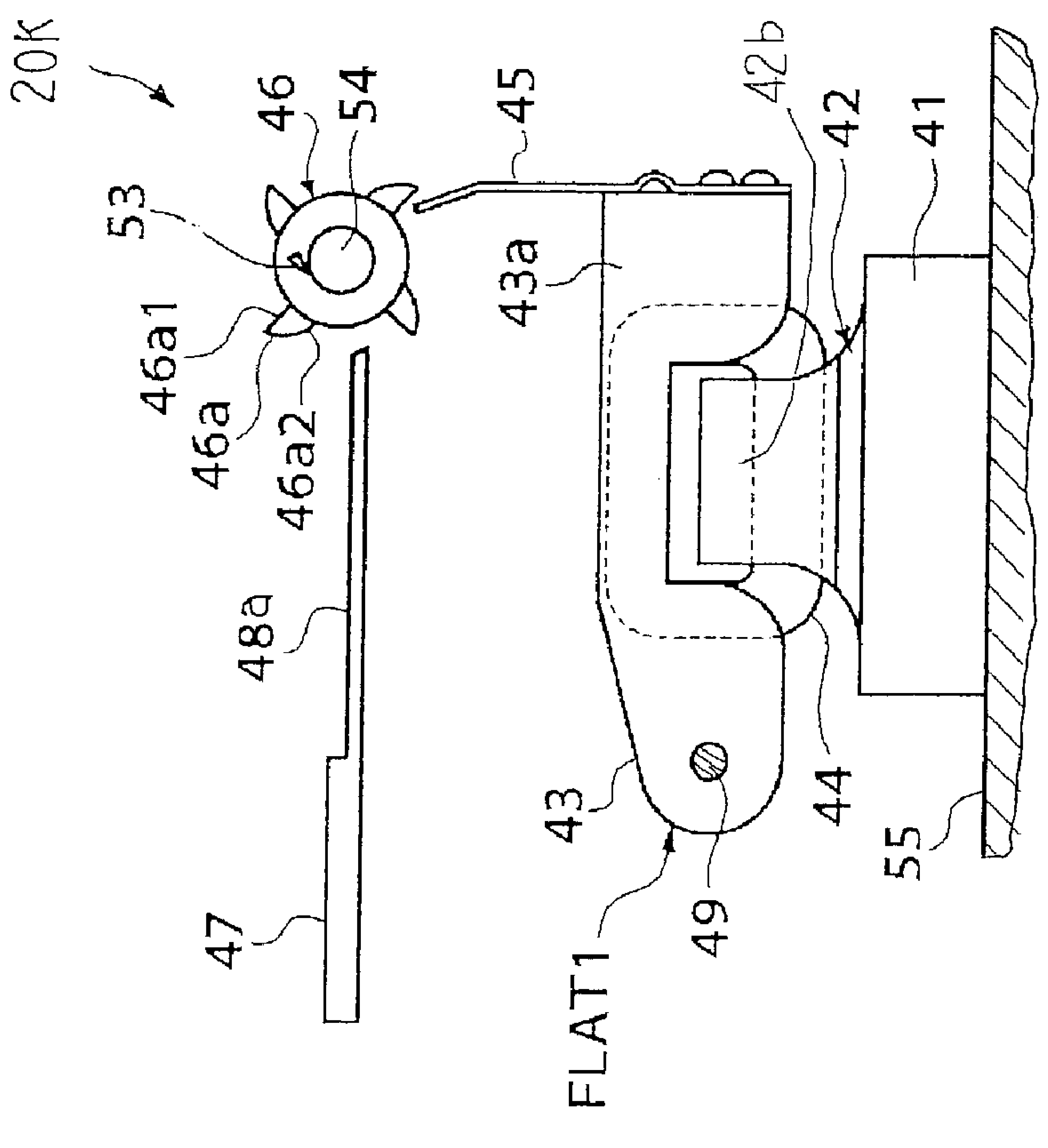


Fig. 33 A

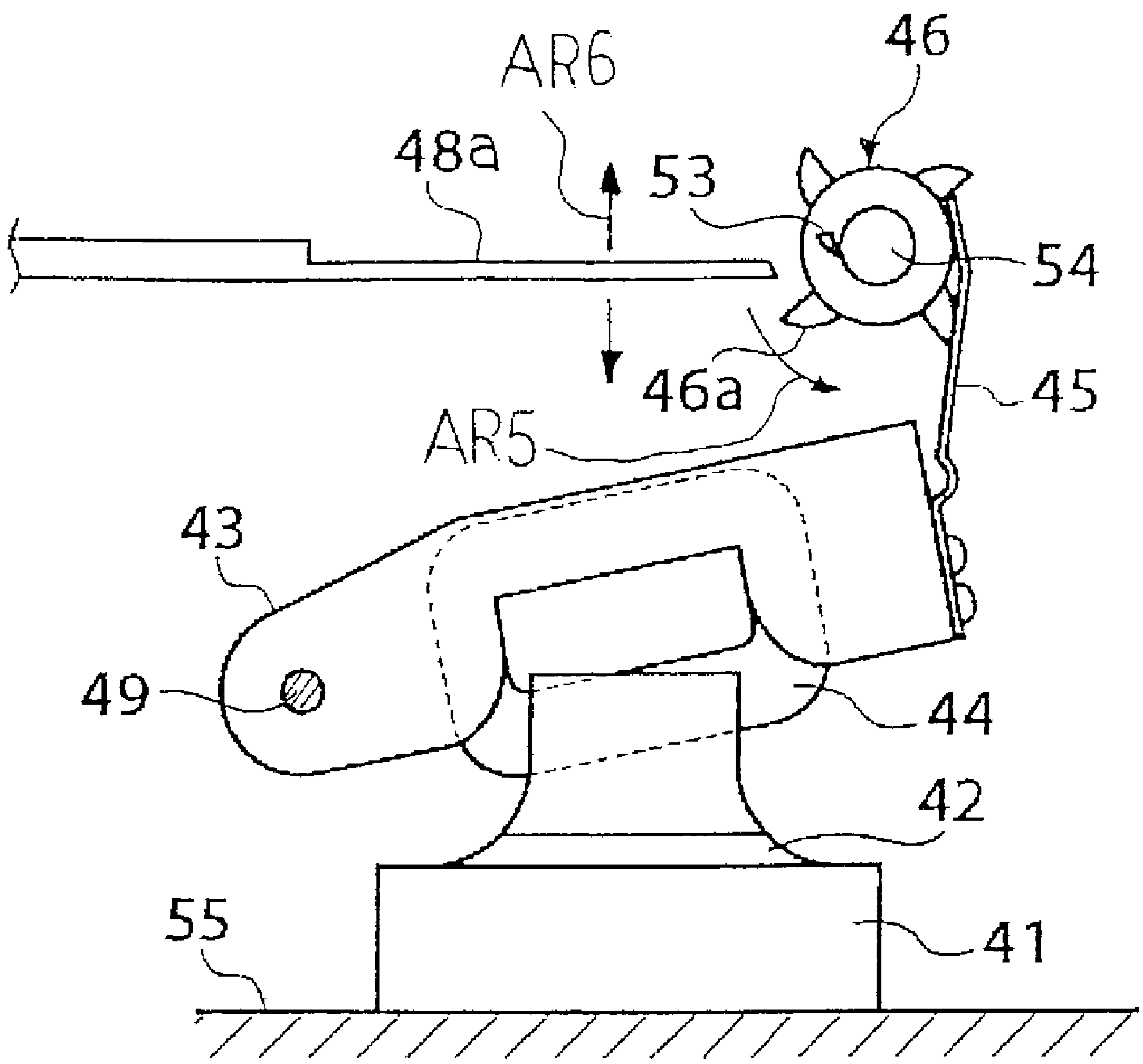


Fig. 34

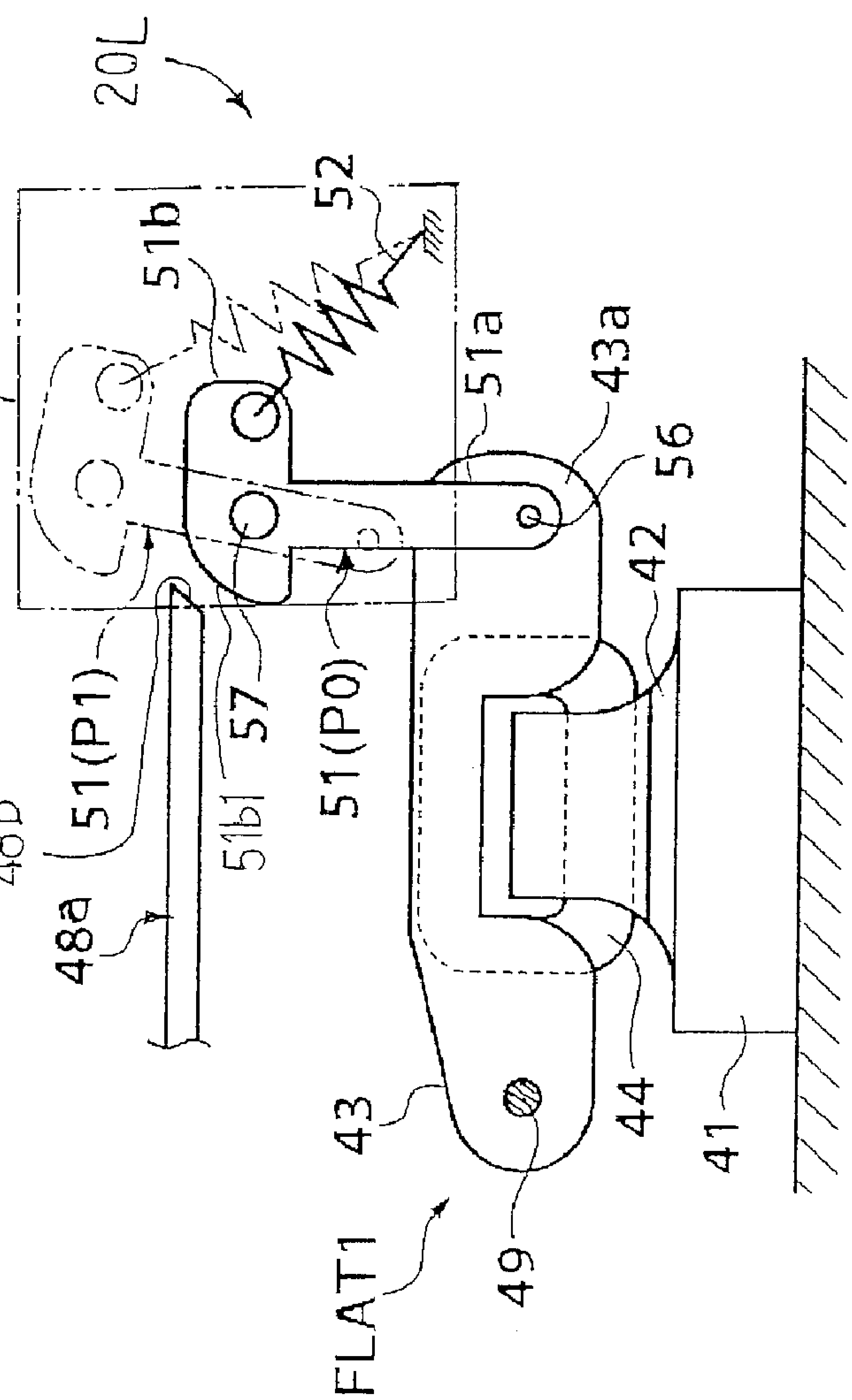


Fig. 35 A

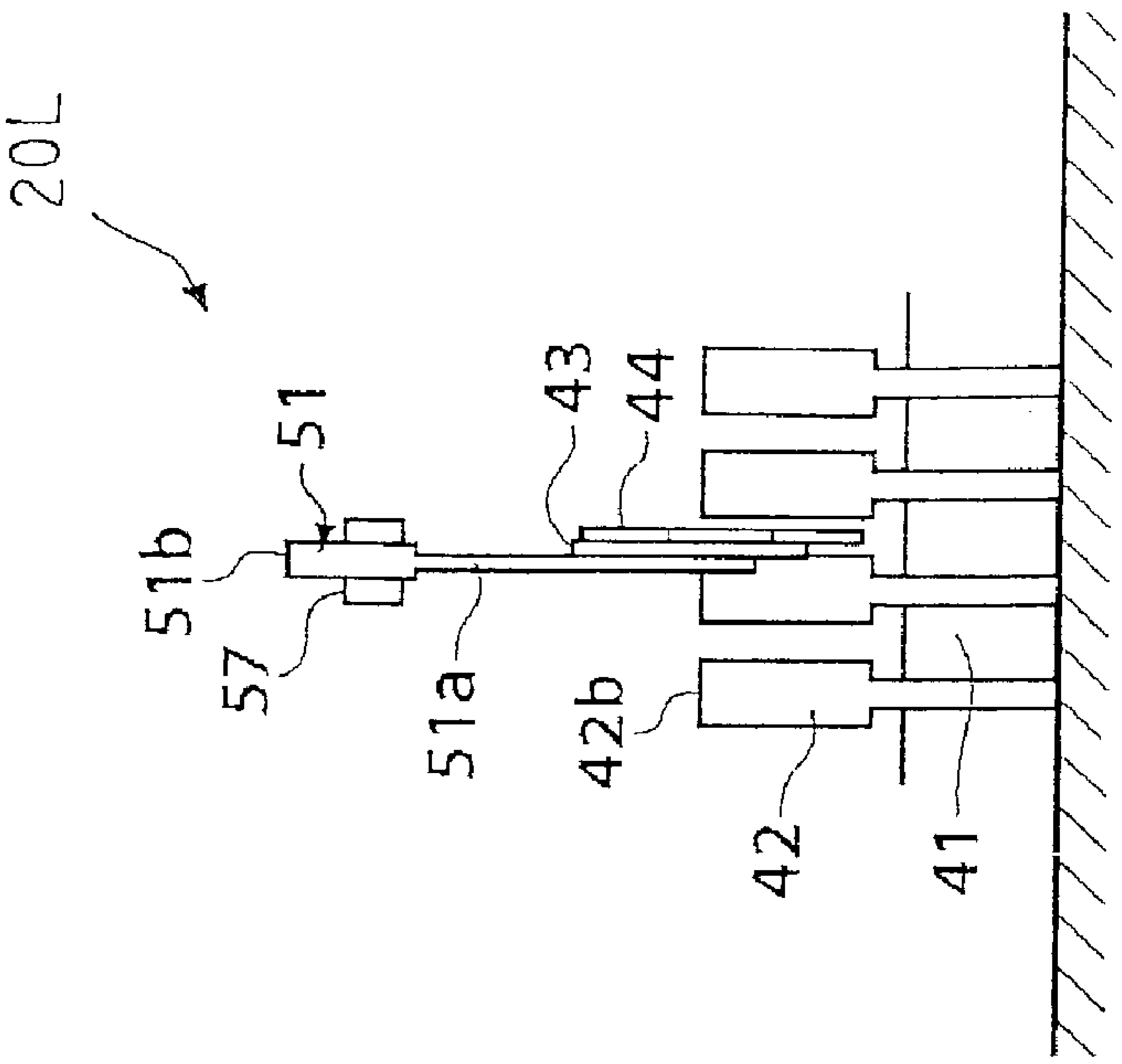


Fig. 35 B

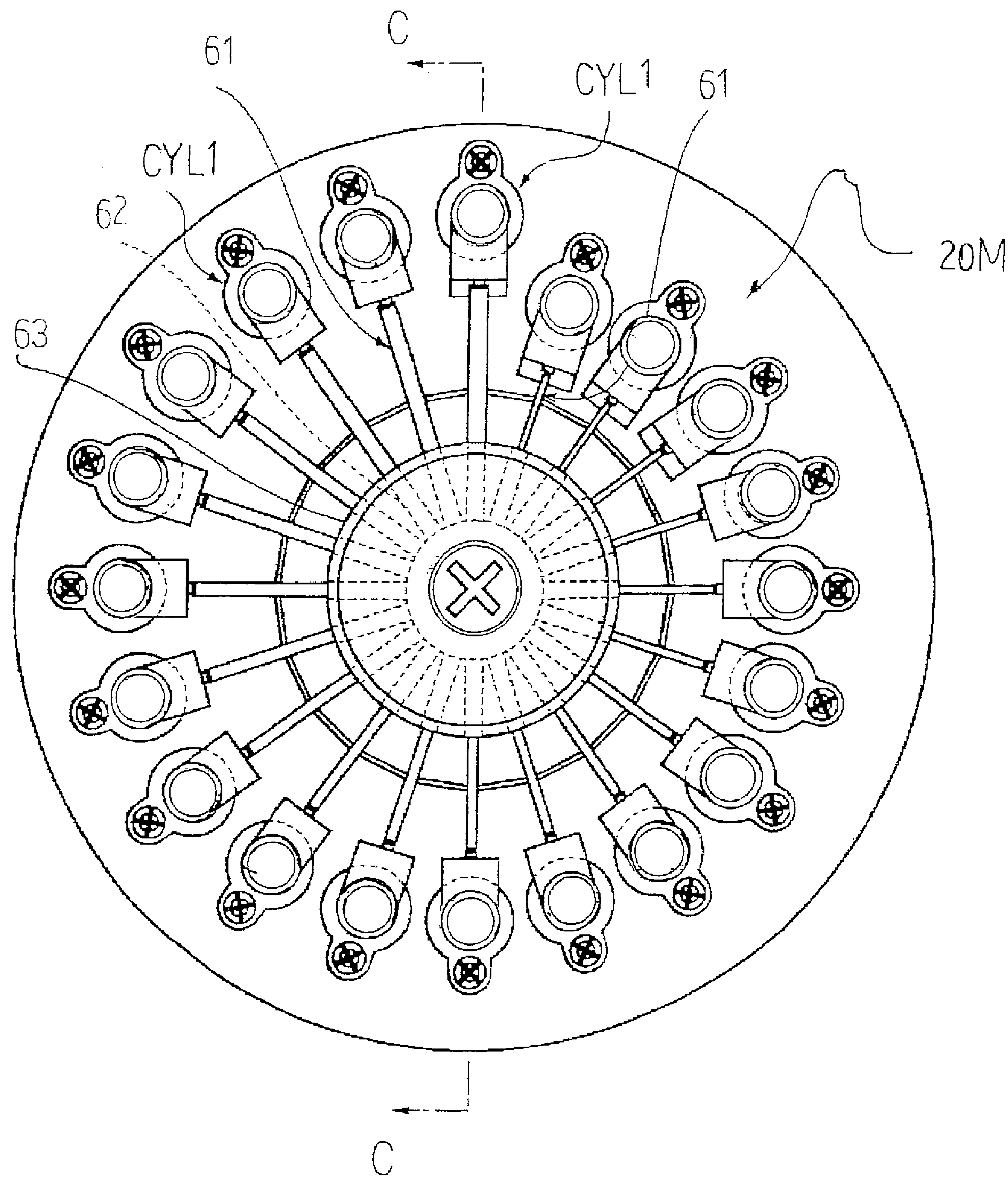


Fig. 36

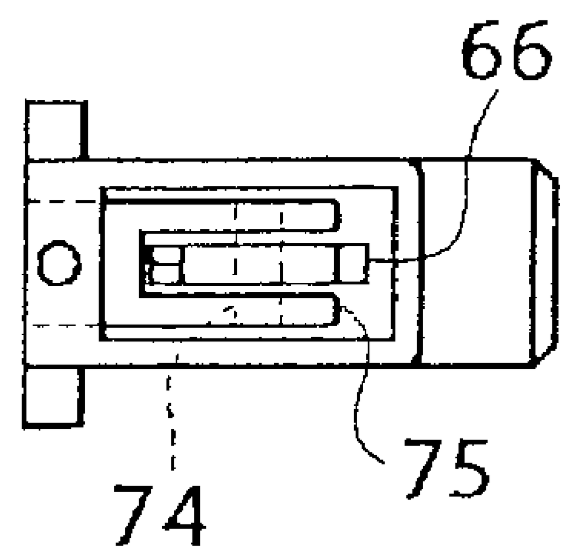


Fig. 37C

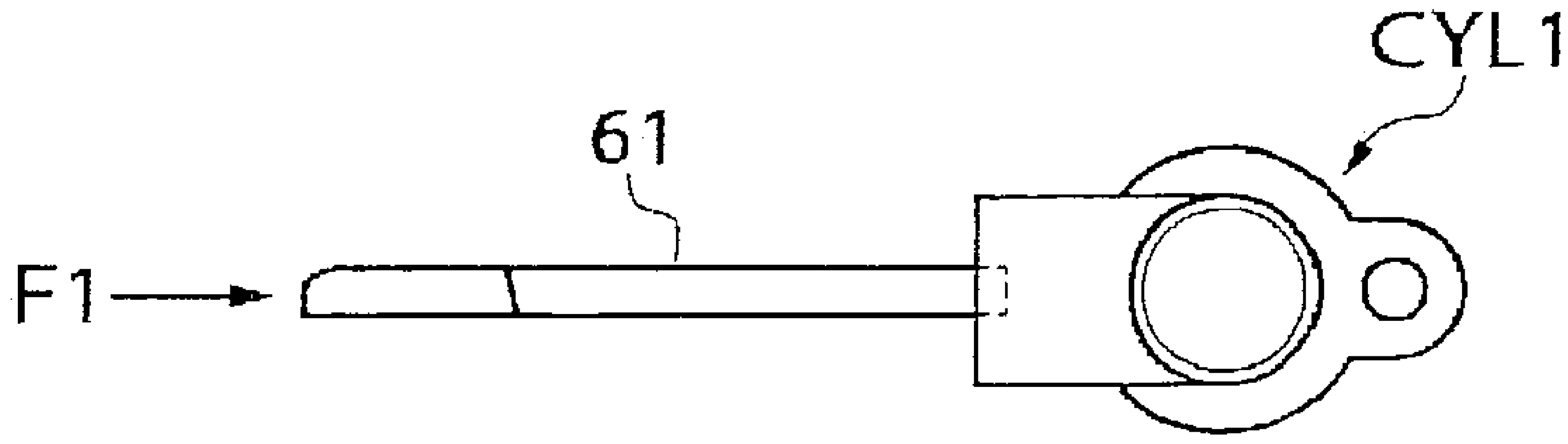


Fig. 37B

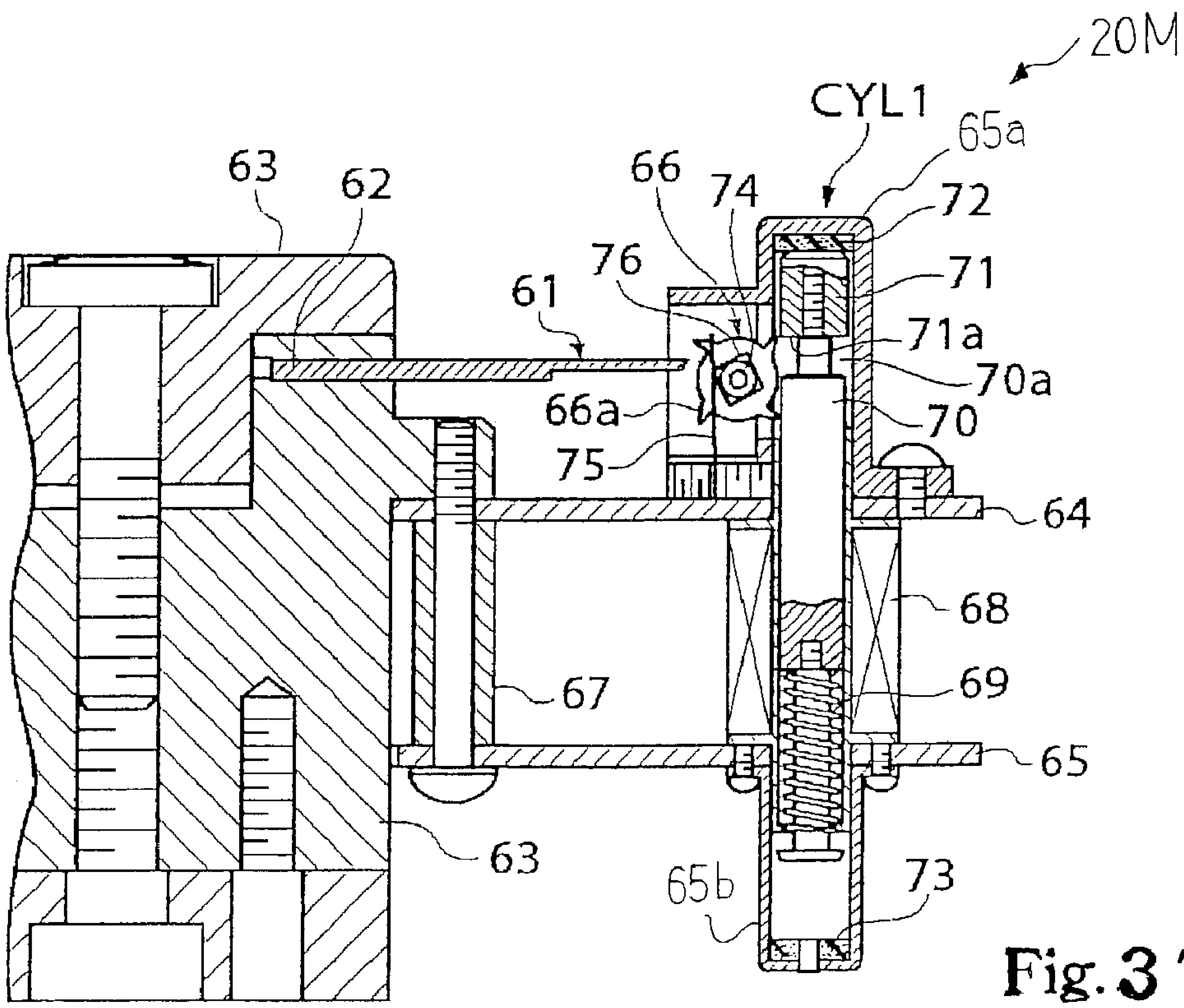
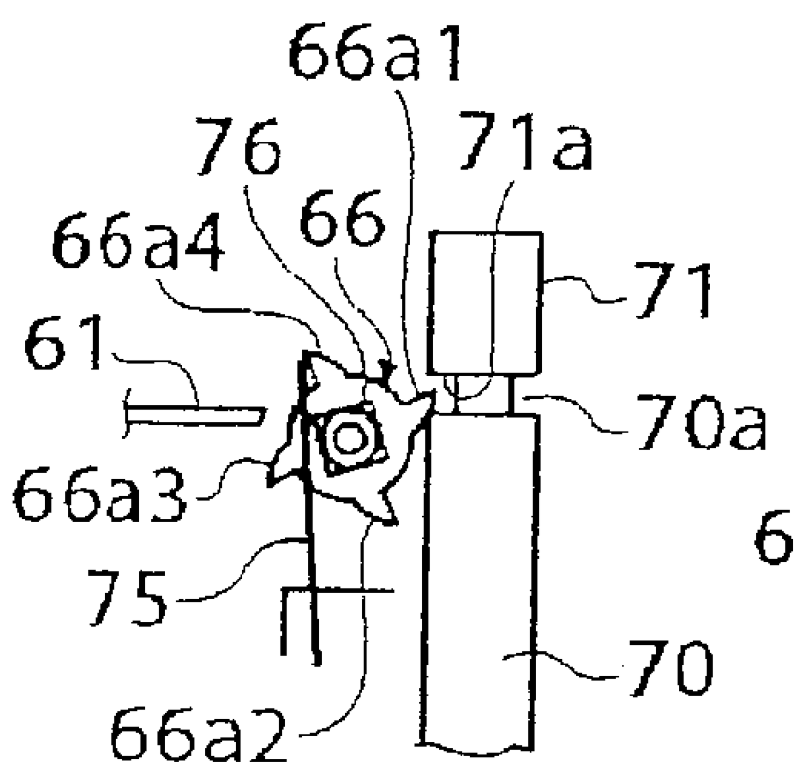
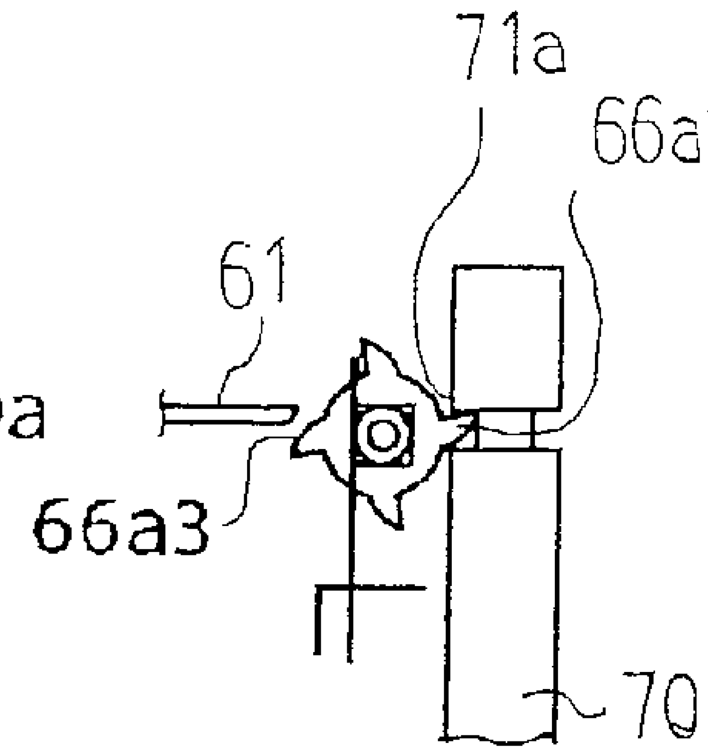
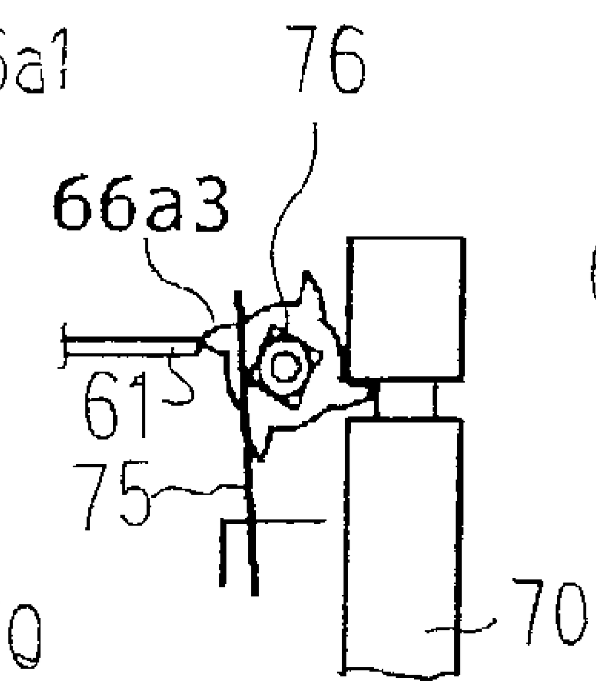


Fig. 37A







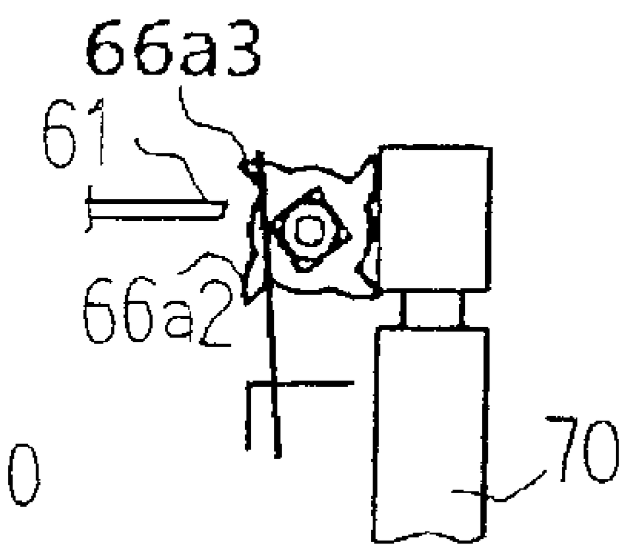
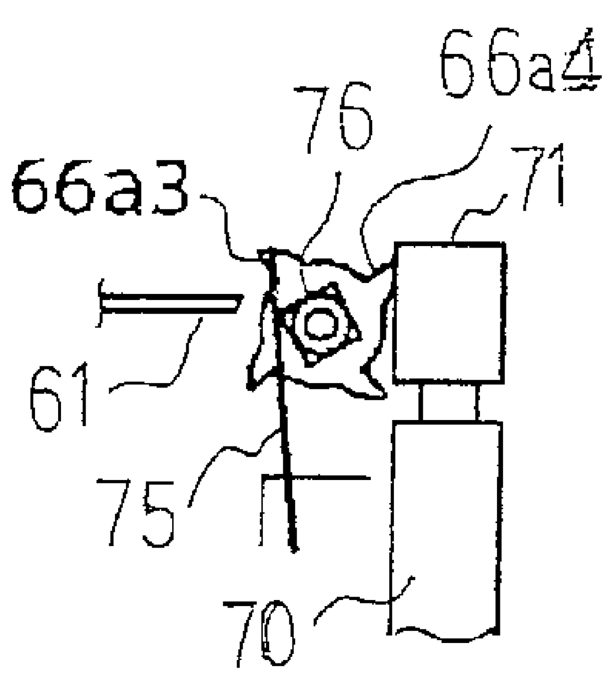
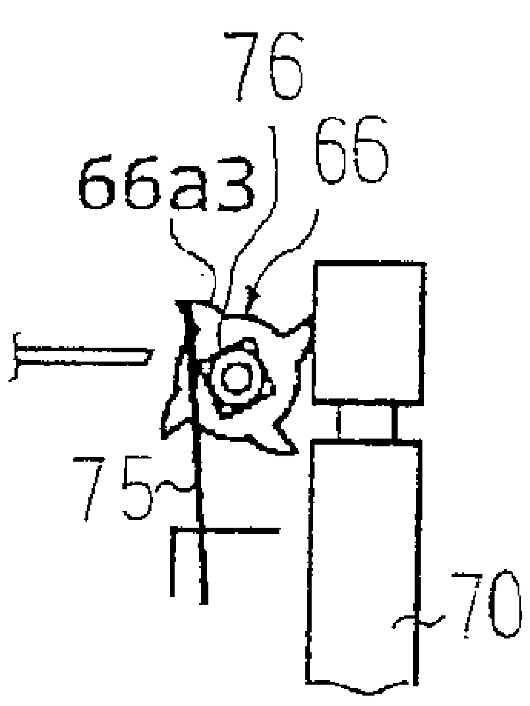
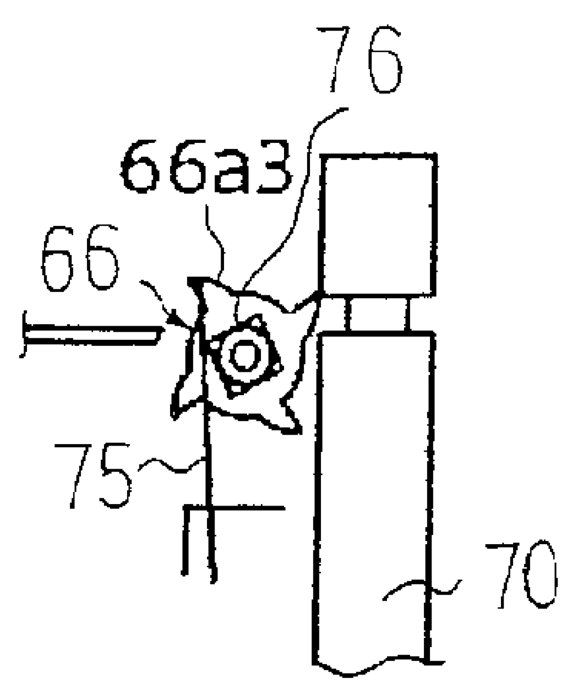


Fig. 38A Fig. 38B Fig. 38C Fig. 38D







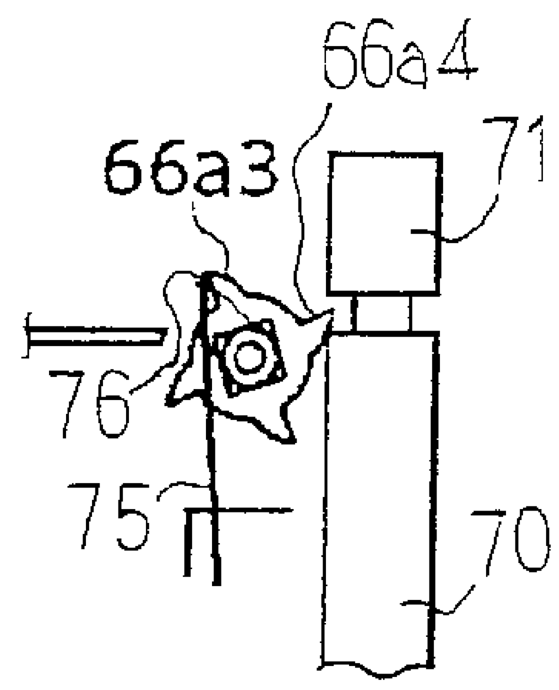


Fig. 38E Fig. 38F Fig. 38G Fig. 38H

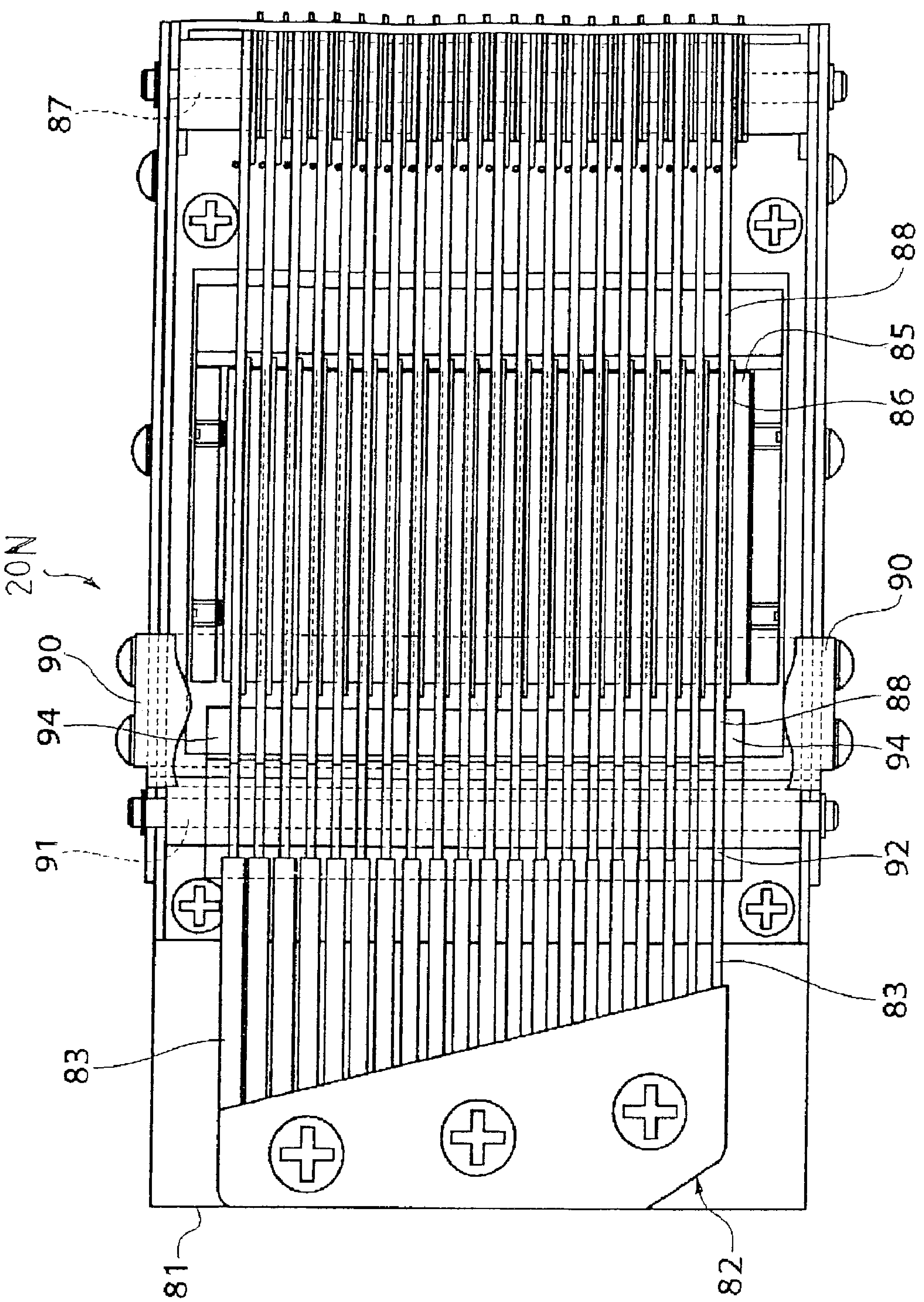


Fig. 39

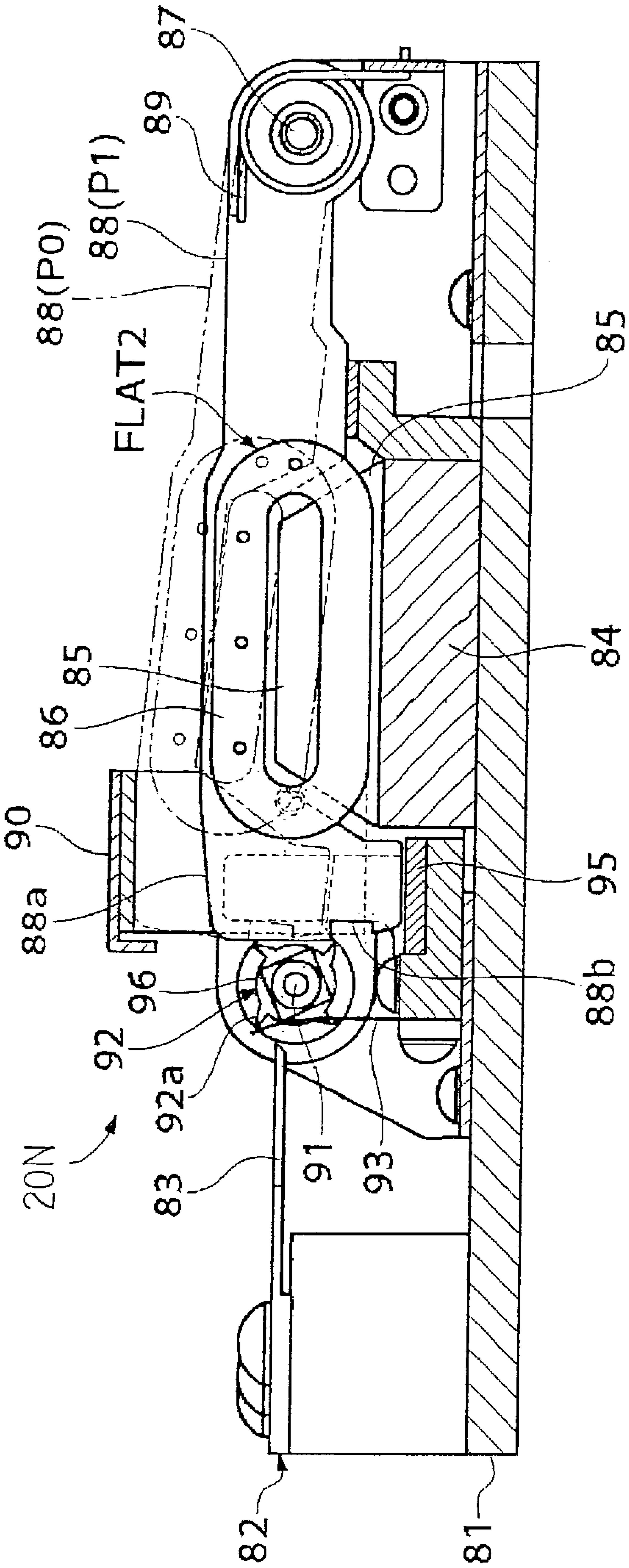


Fig. 40A

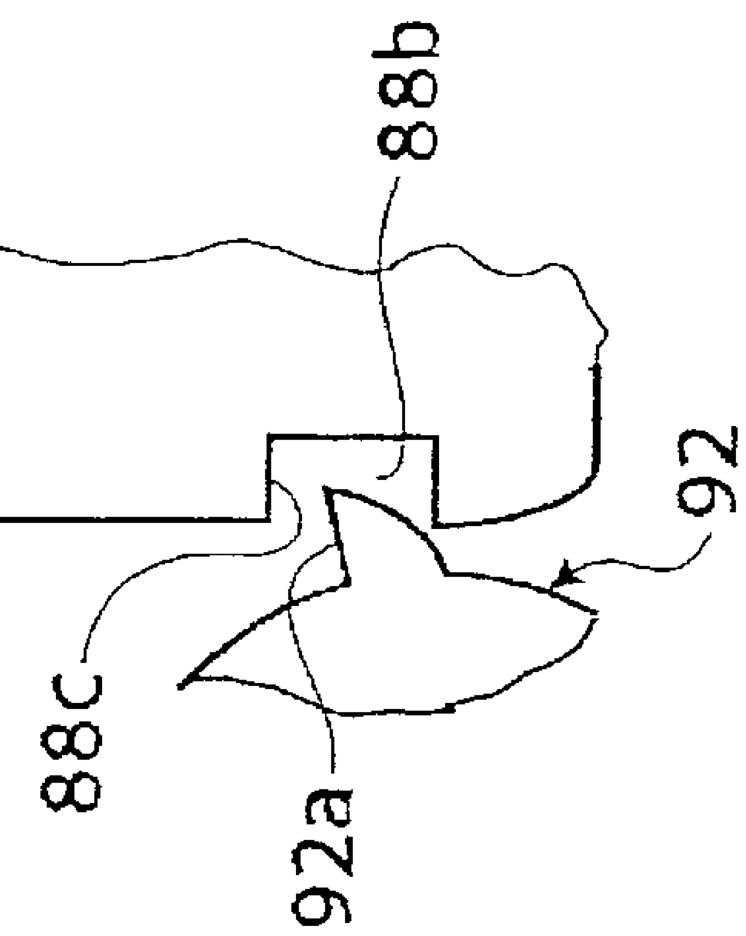


Fig. 40C

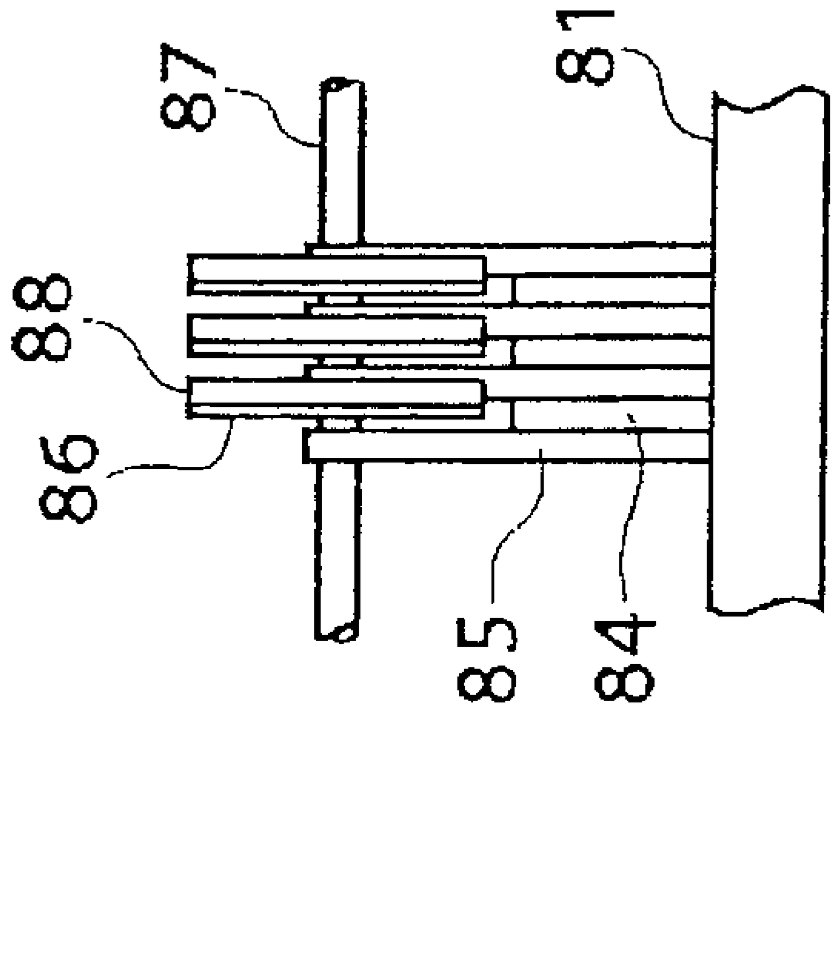


Fig. 40B

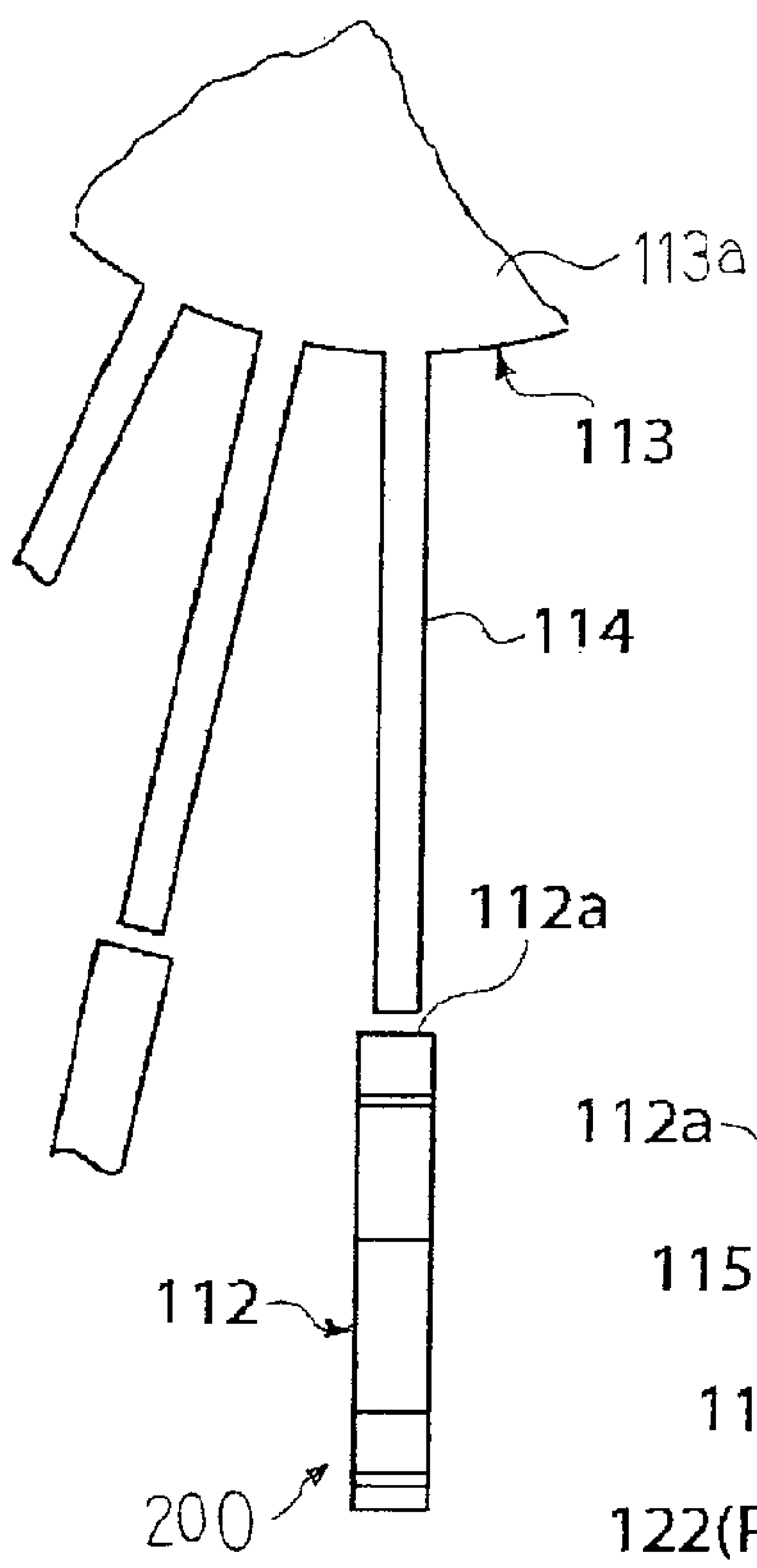


Fig. 41 A

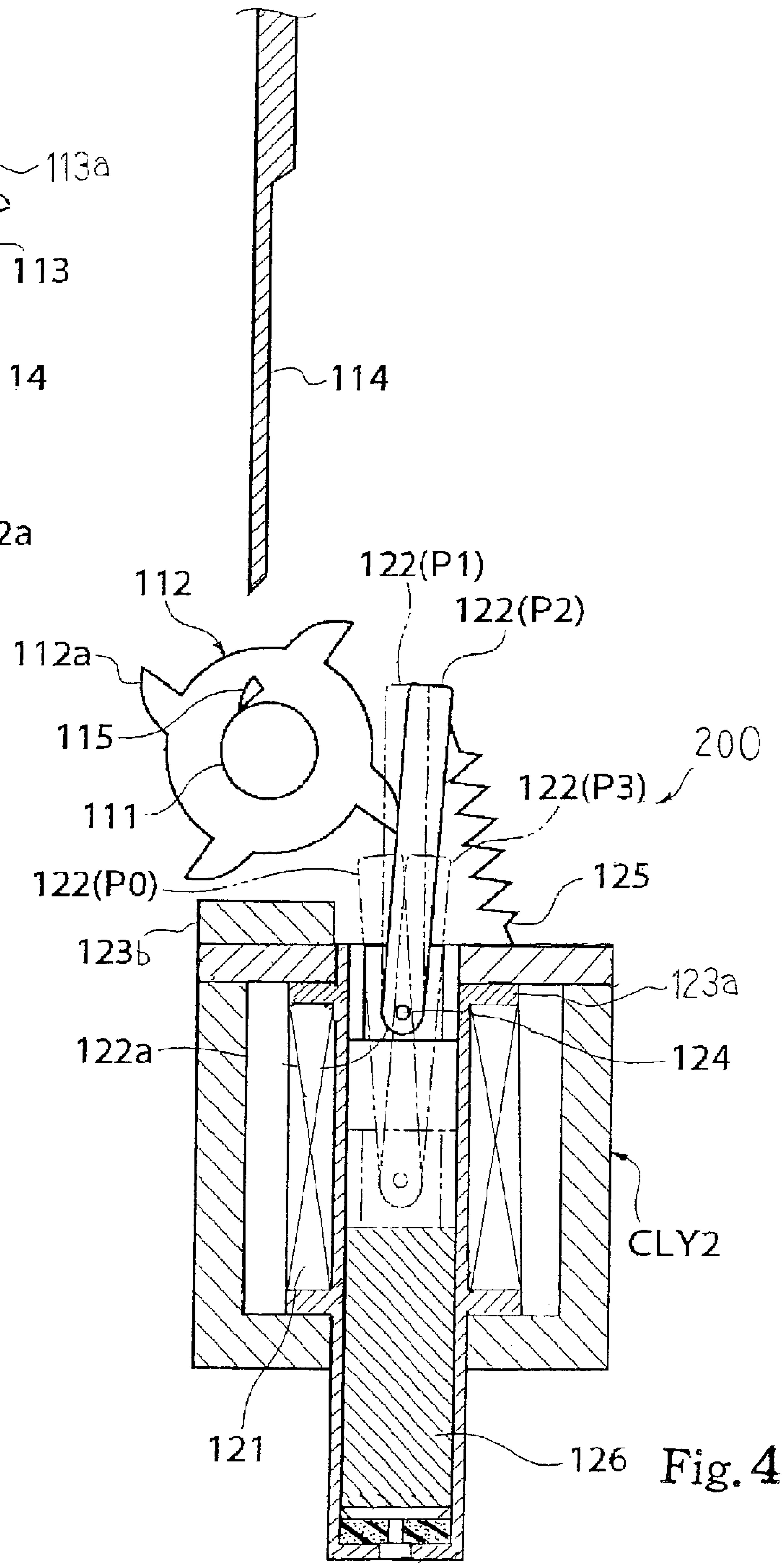


Fig. 41 B

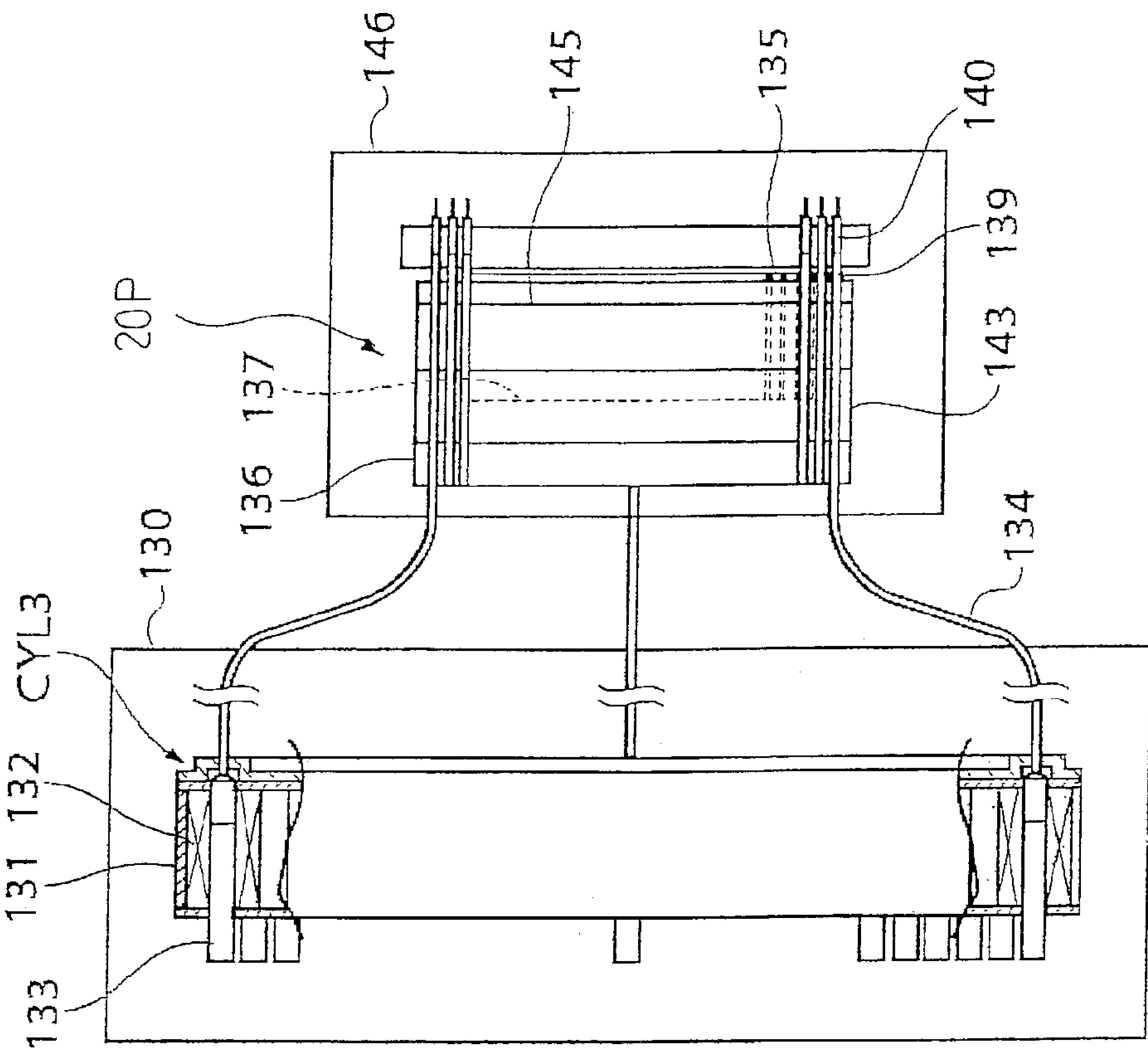


Fig. 42B

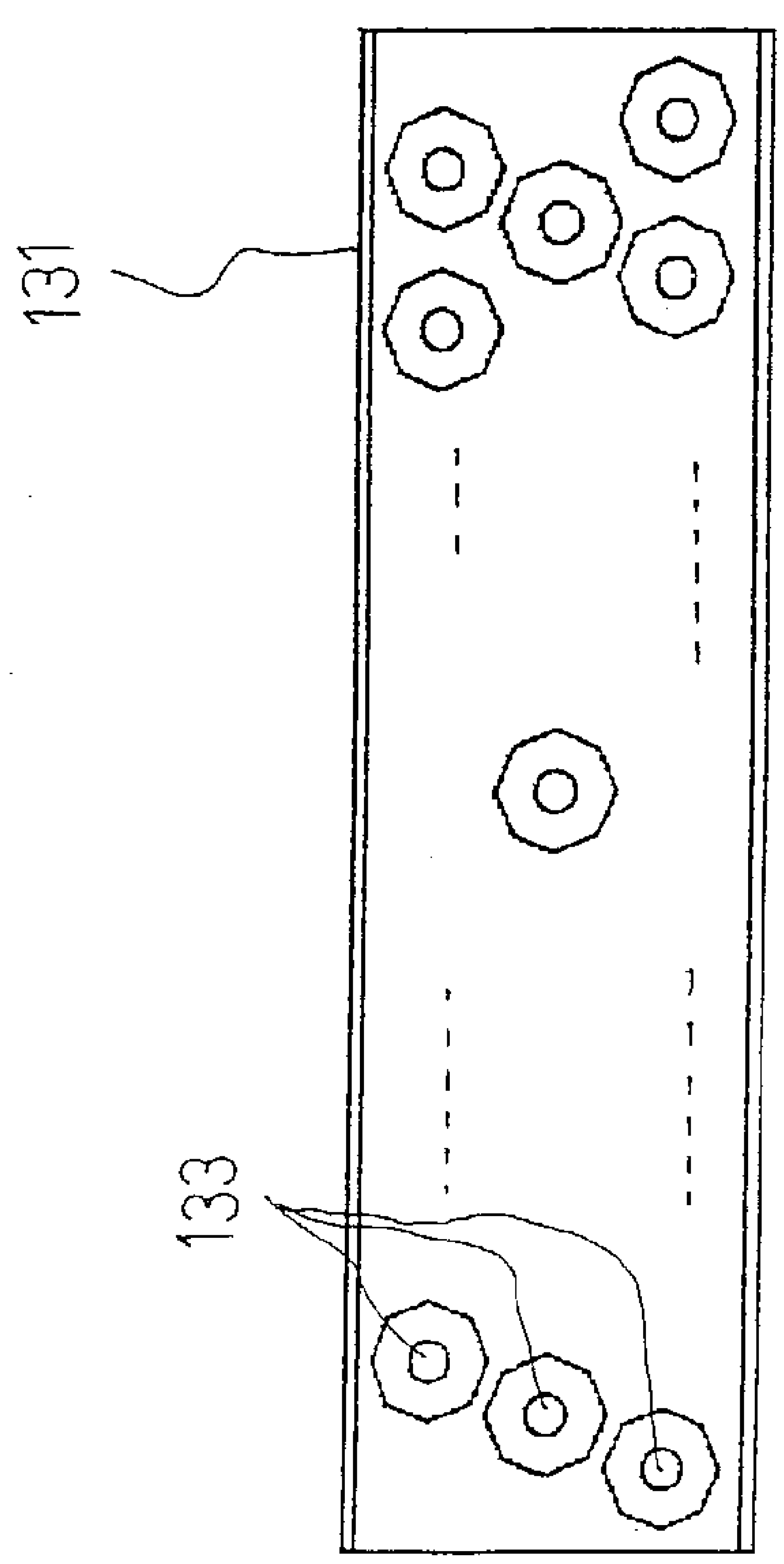


Fig. 42A

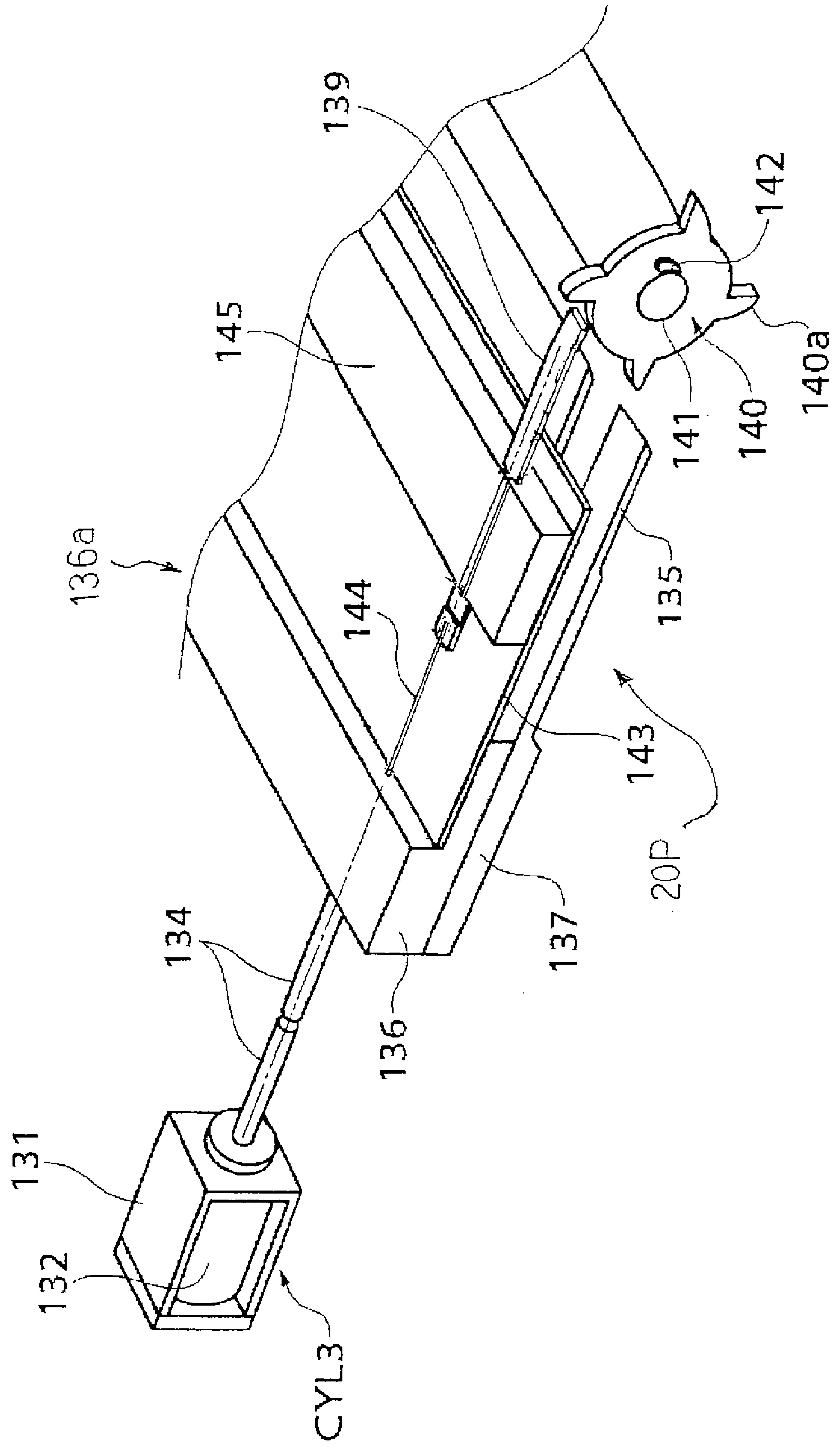

131
132
CYL3
134
136
137
20P
143
135
144
136a
145
139
142
141
140
140a

Fig. 43

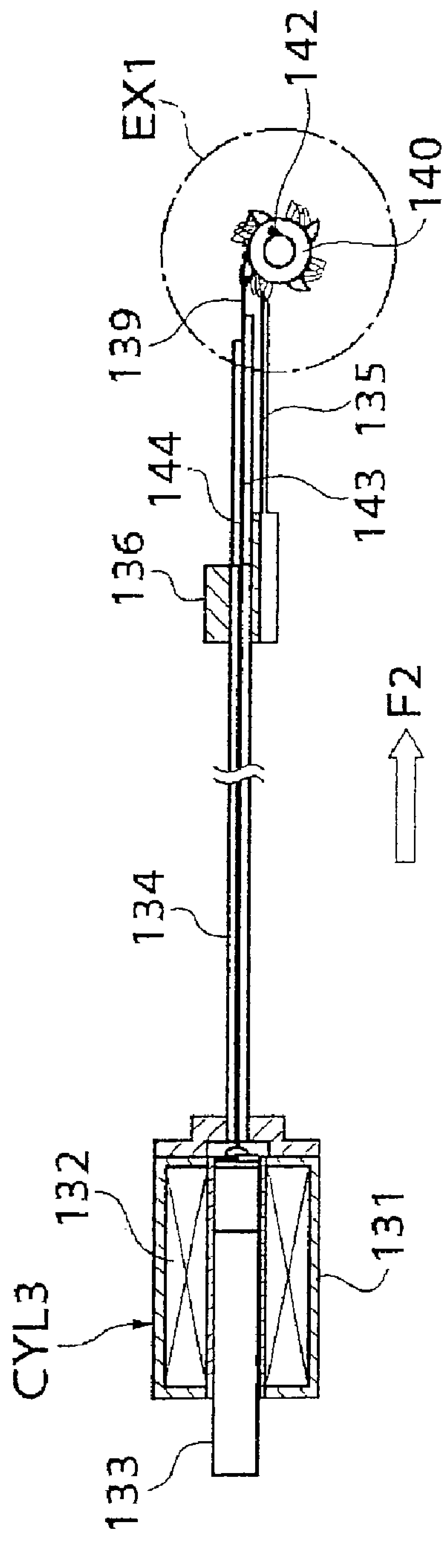


Fig. 44A

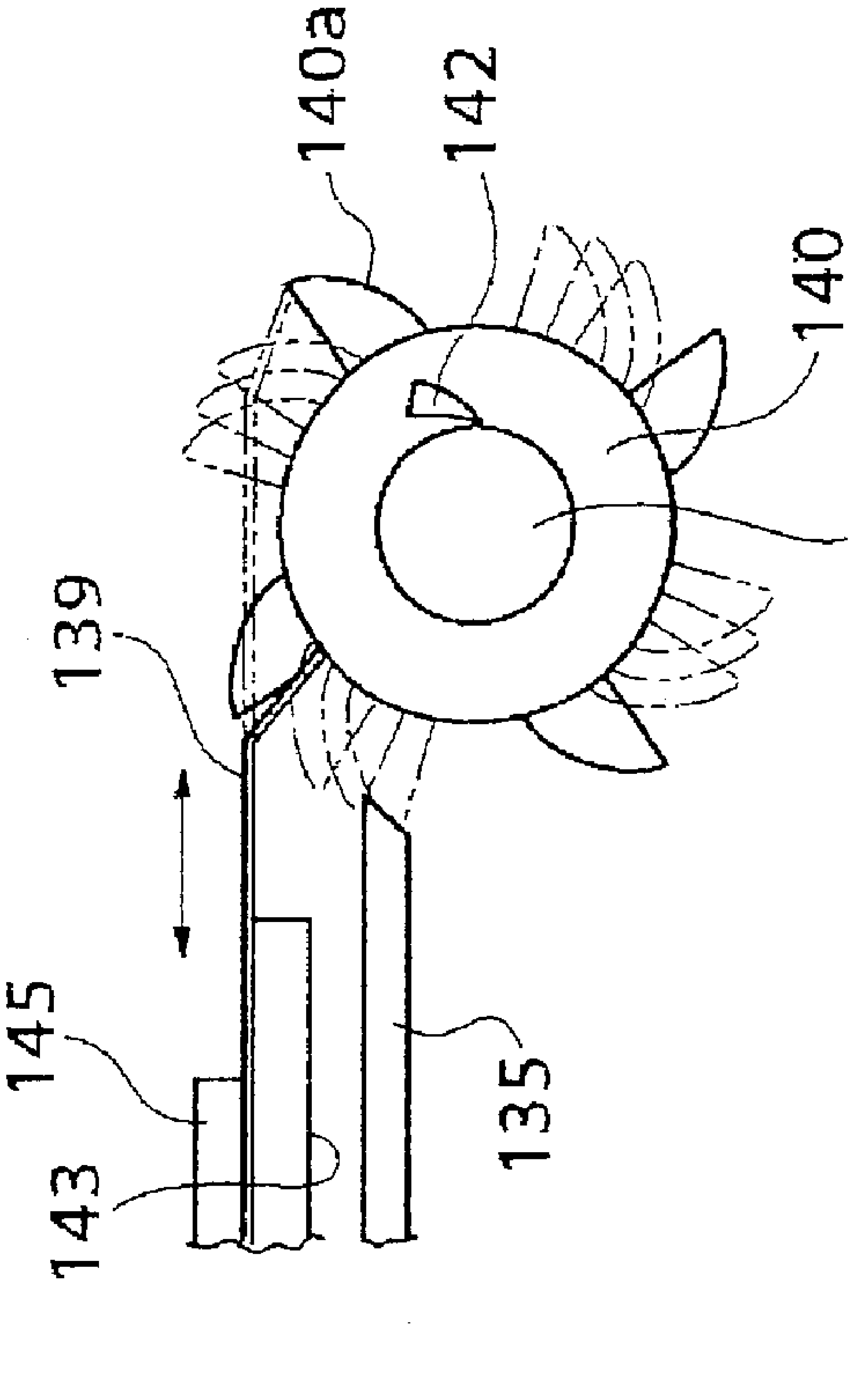


Fig. 44B

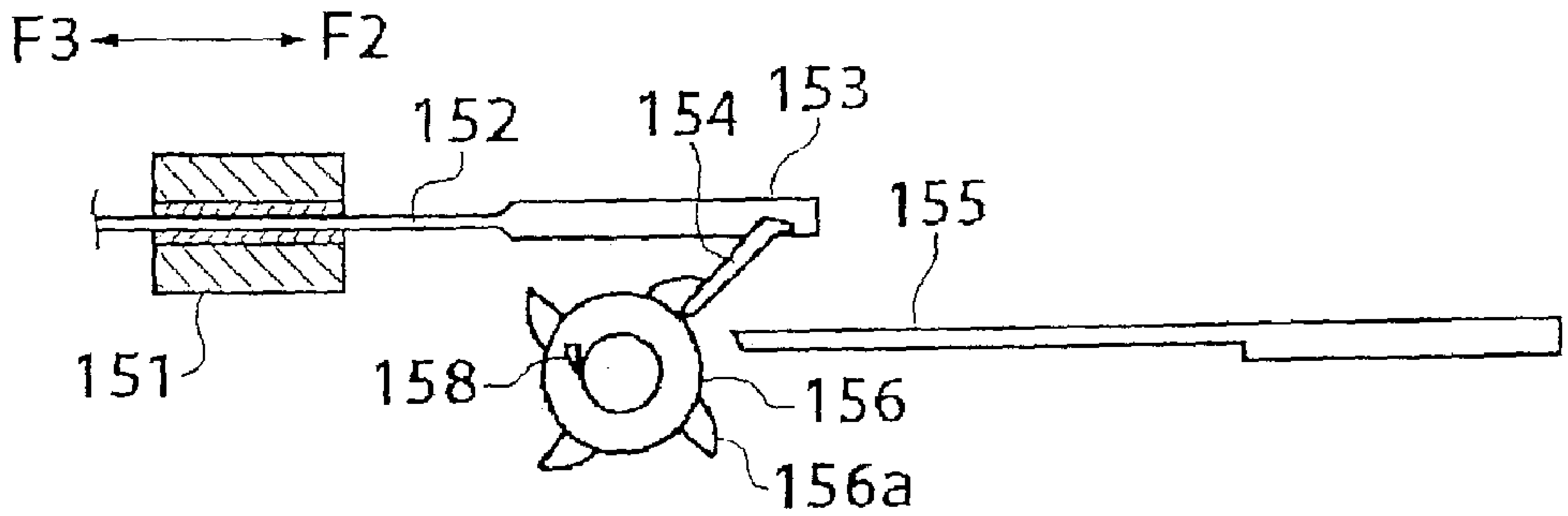


Fig. 45A

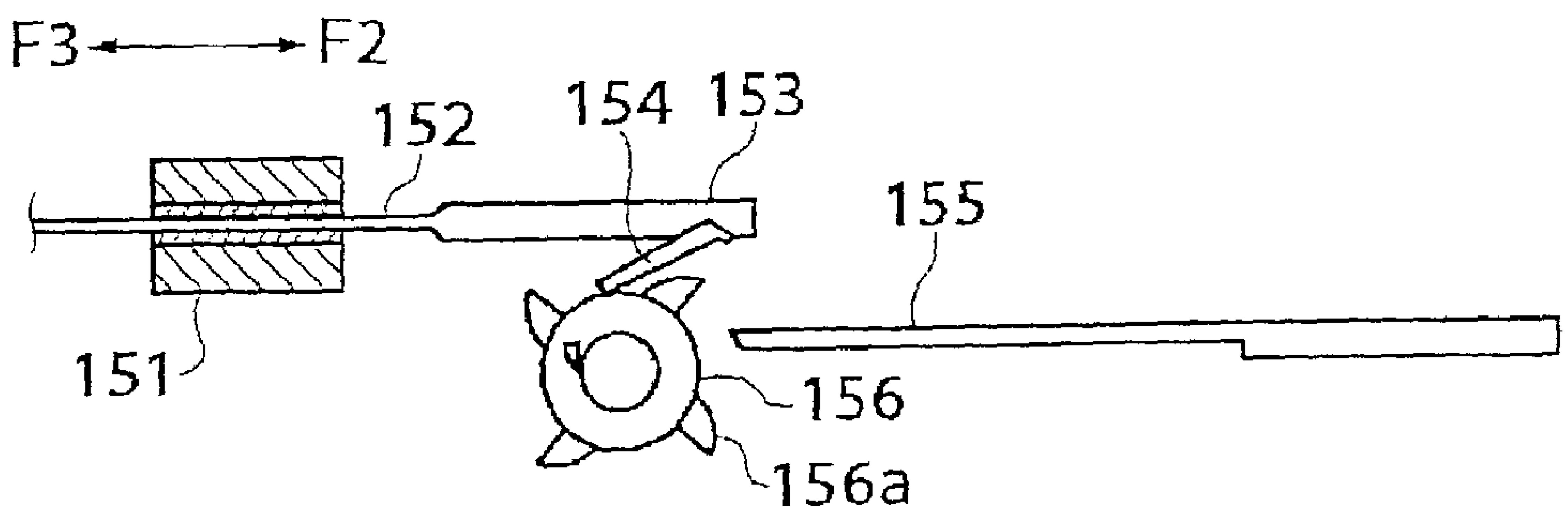


Fig. 45B

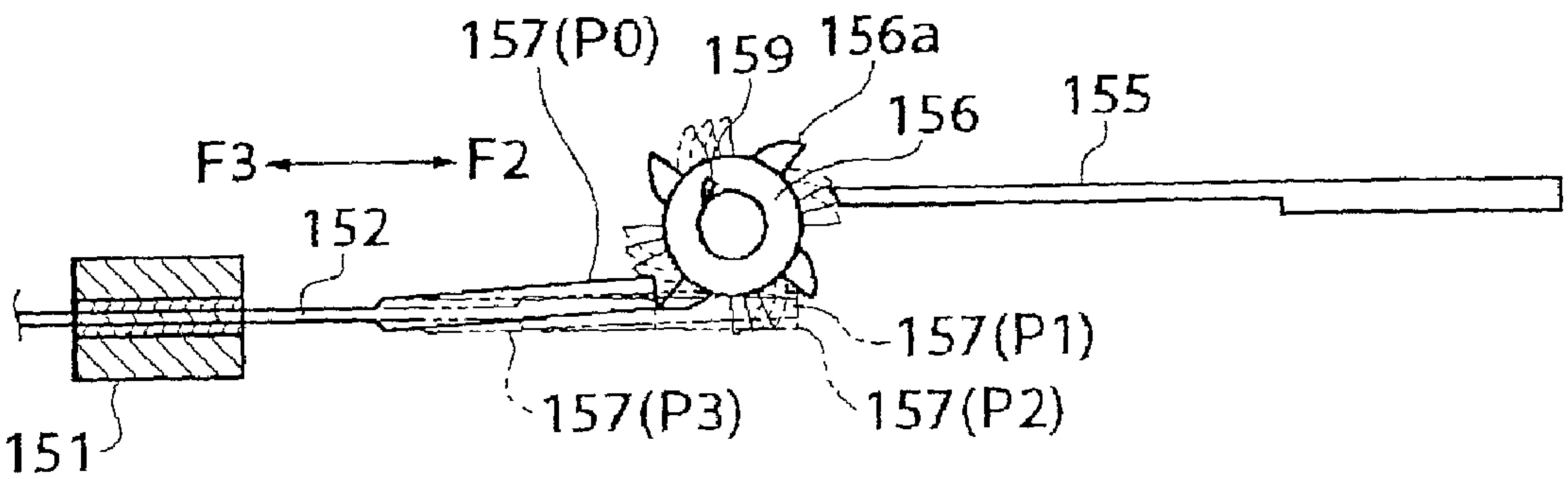


Fig. 45C

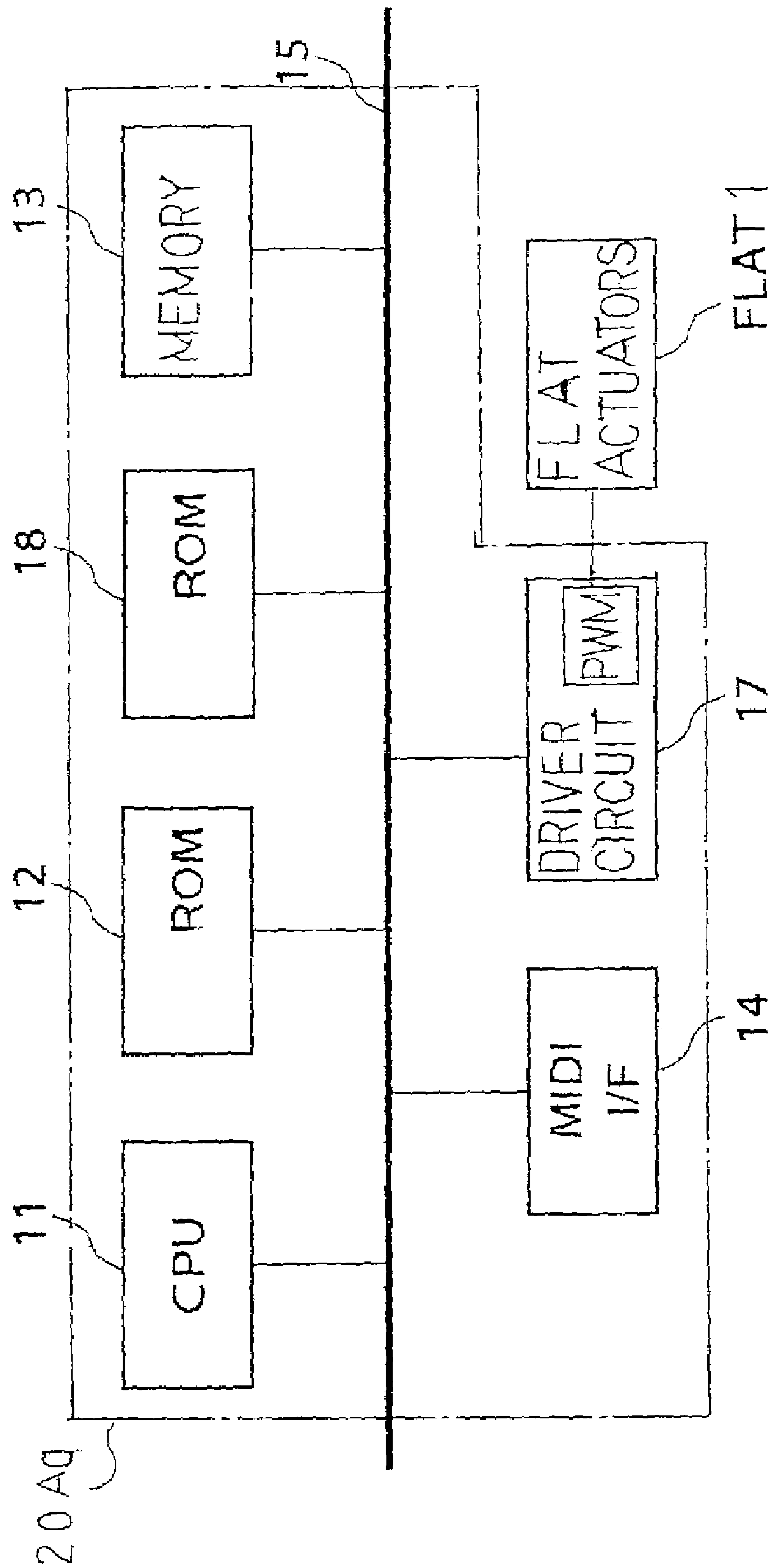

15
13
MEMORY
18
ROM
12
ROM
11
CPU
FLAT ACTUATORS
FLAT 1
DRIVER CIRCUIT
PWM
17
MIDI I/F
14
20Aq

Fig. 46

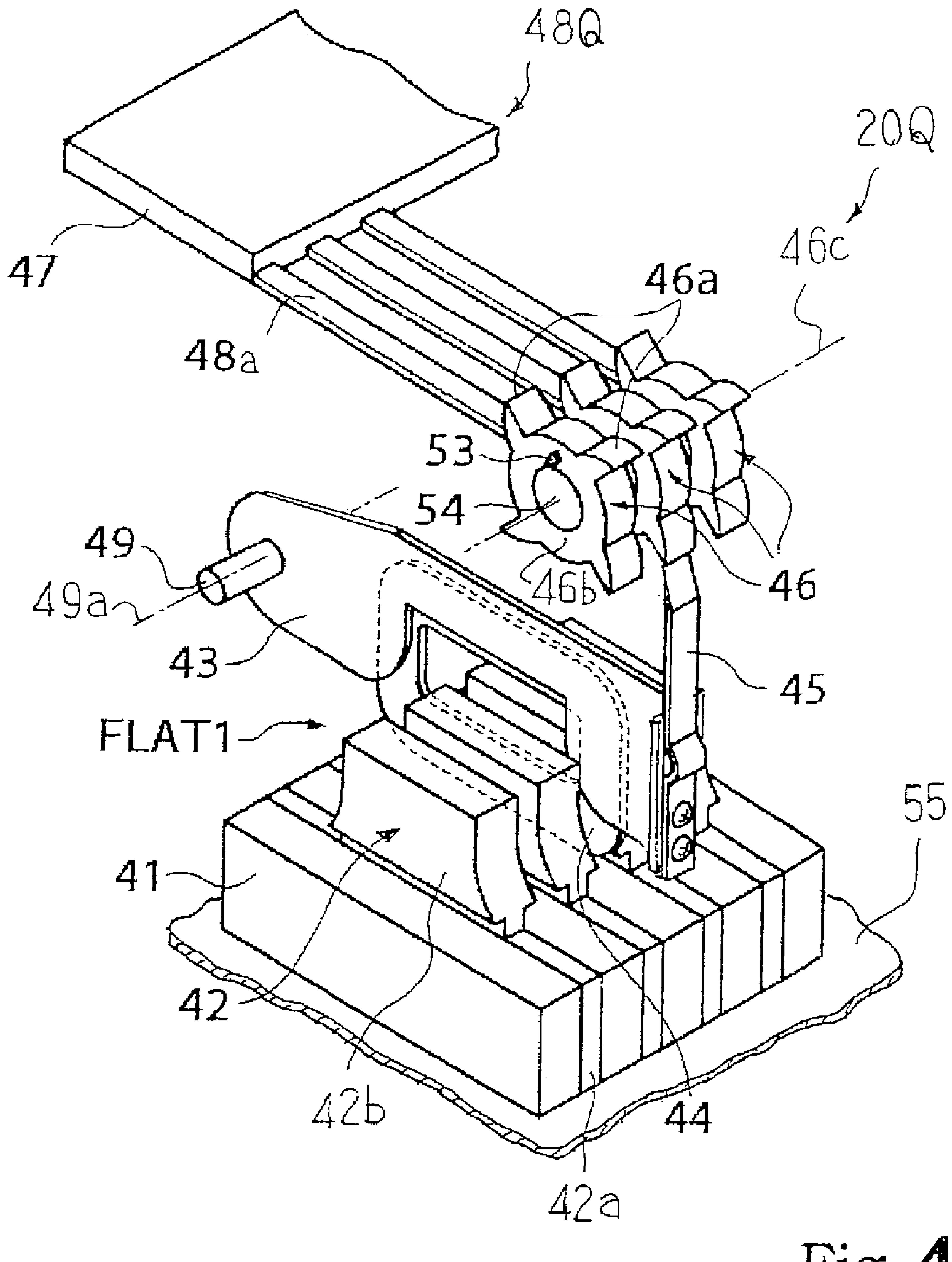

48Q
20Q
47
46c
46a
48a
53
54
49
49a
46b
46
43
45
FLAT1
55
41
42
42b
44
42a

Fig. 47

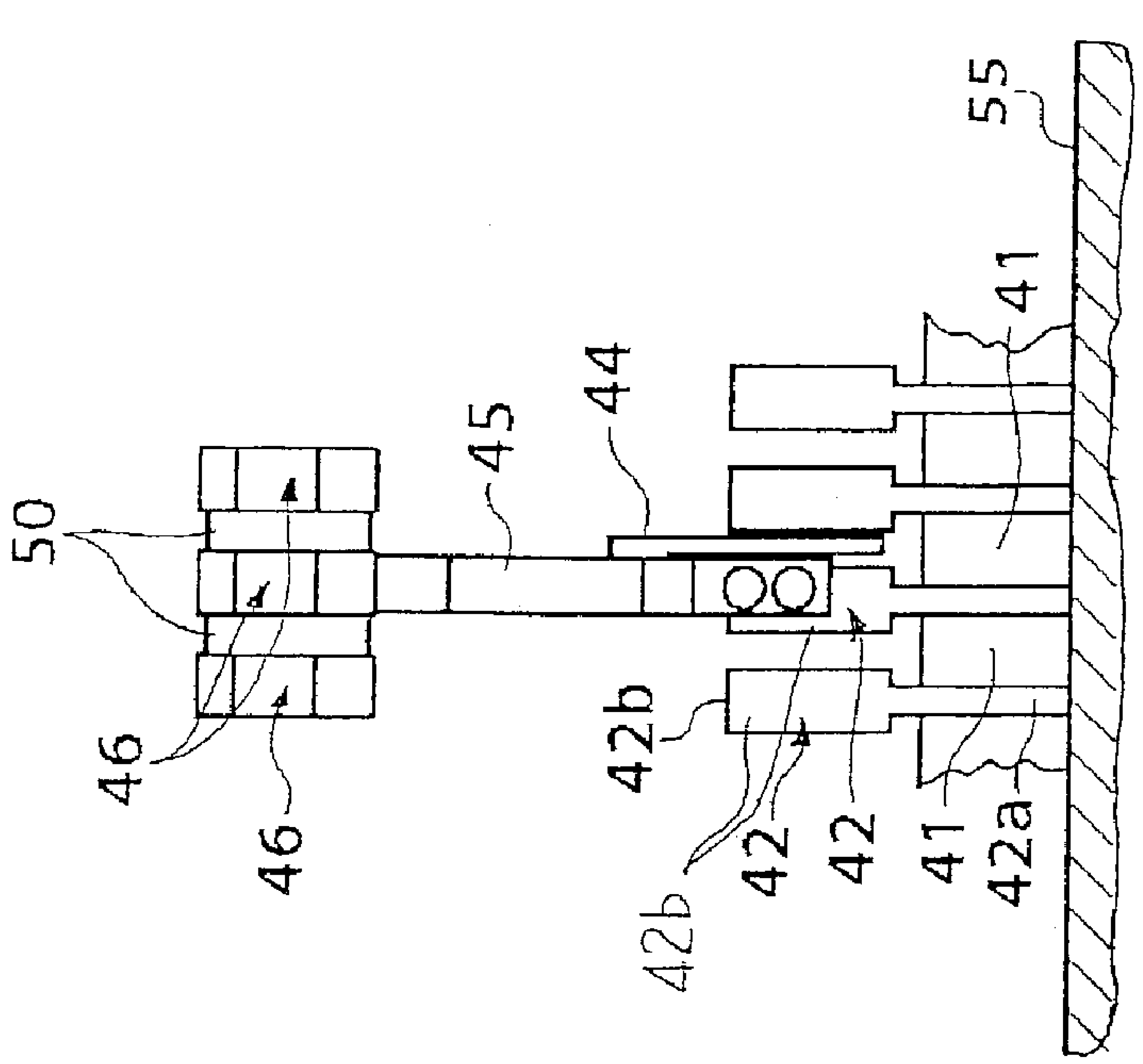


Fig. 48 B

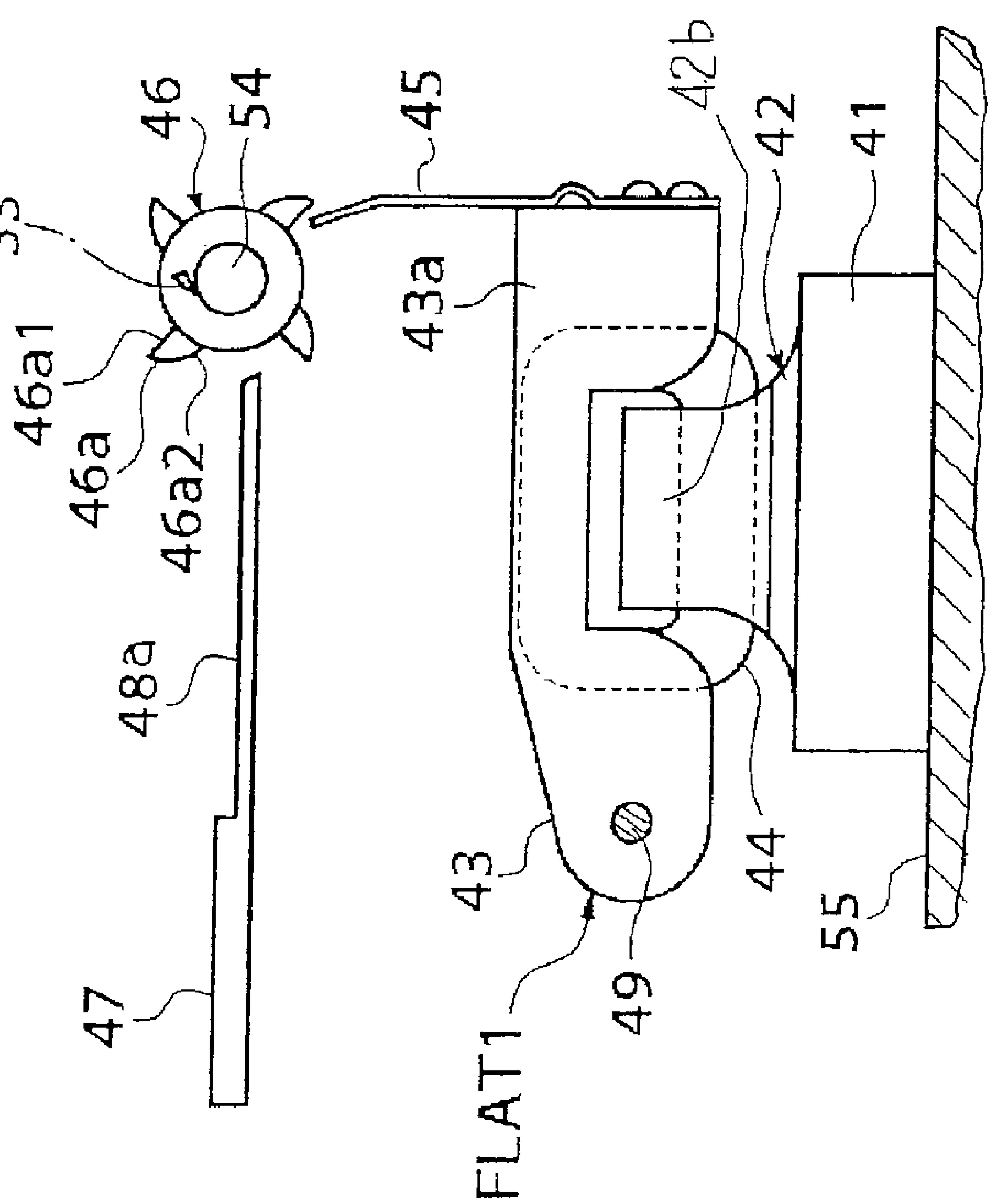


Fig. 48 A

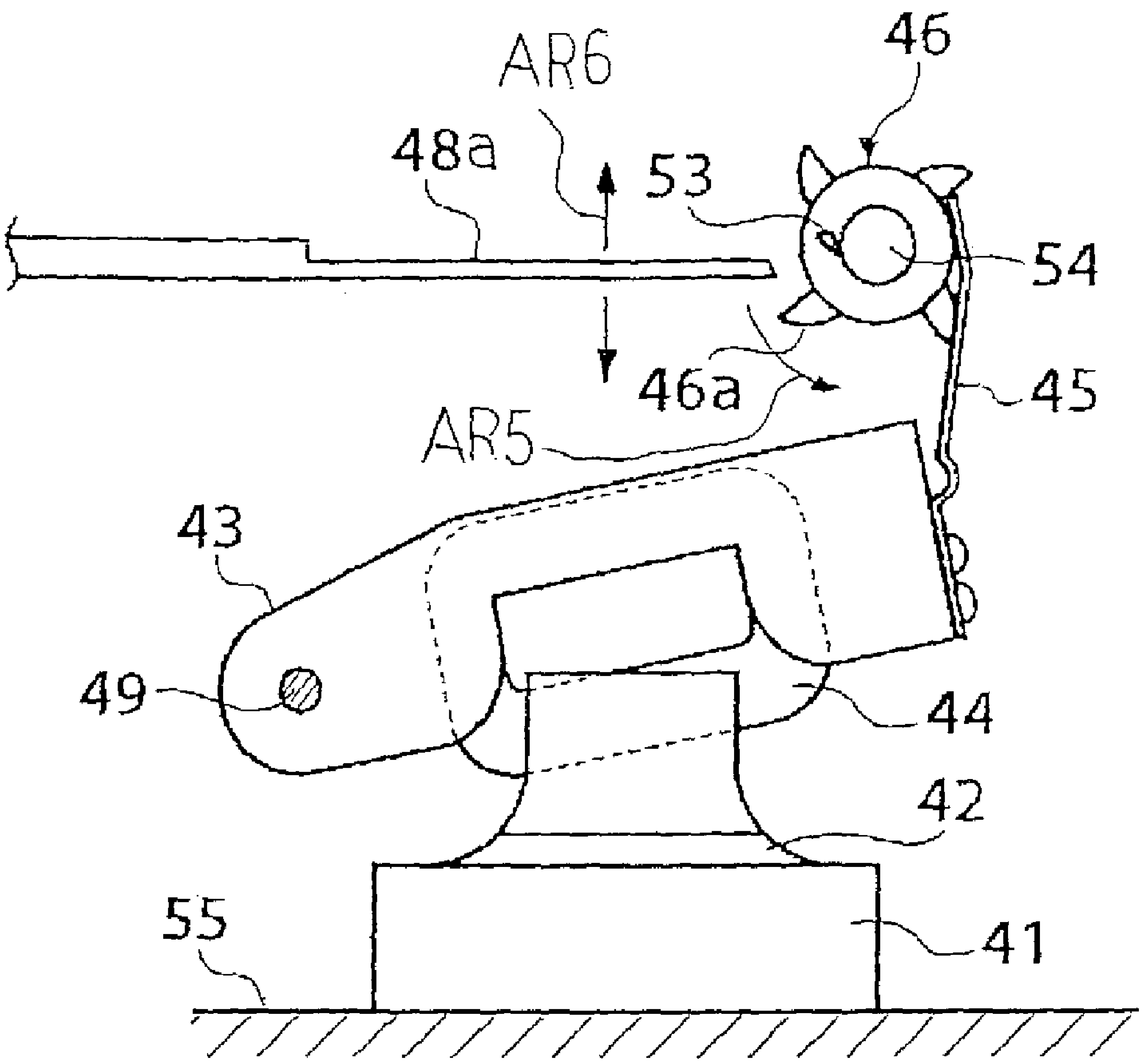


Fig. 49

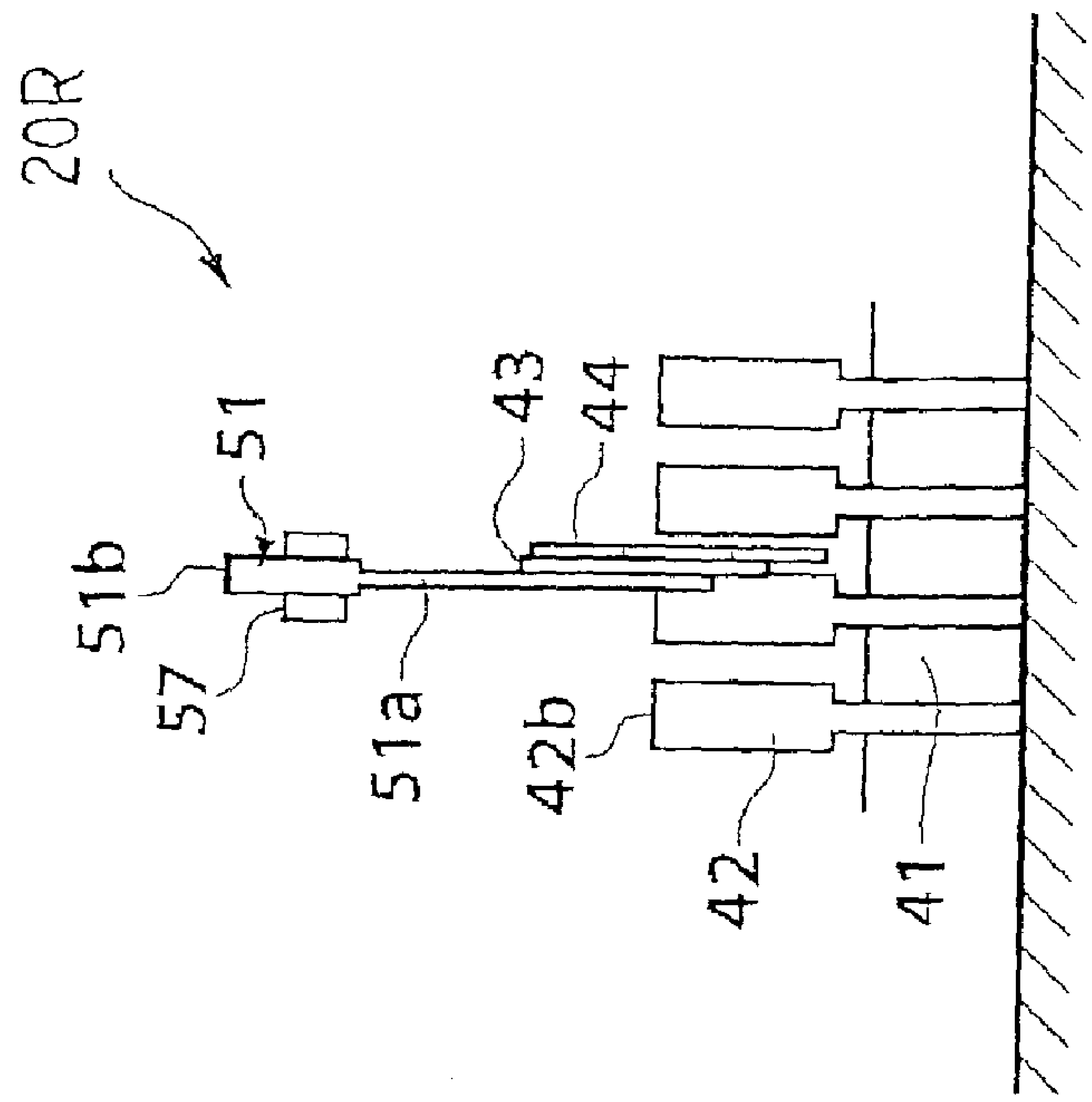


Fig. 50 B

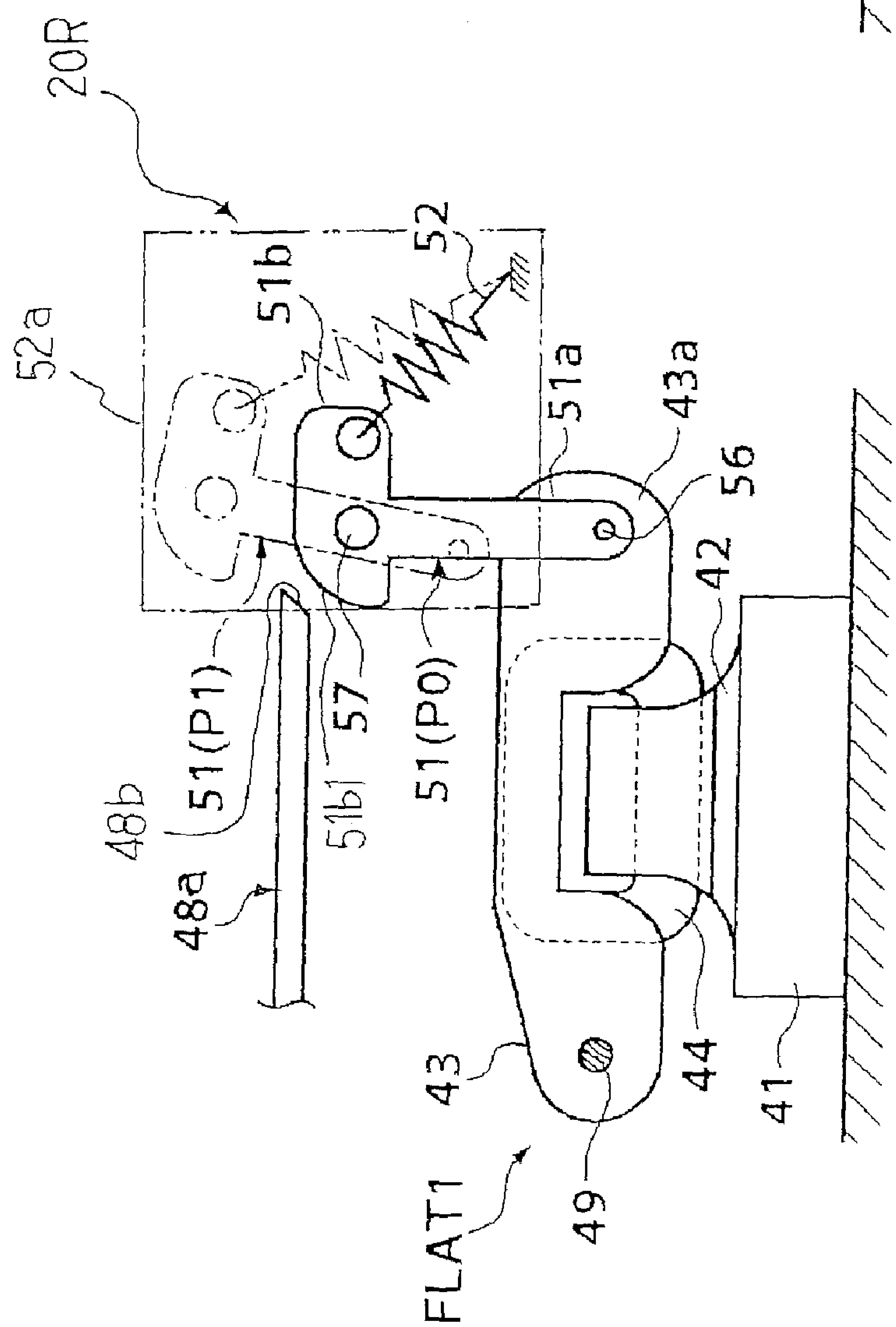


Fig. 50 A

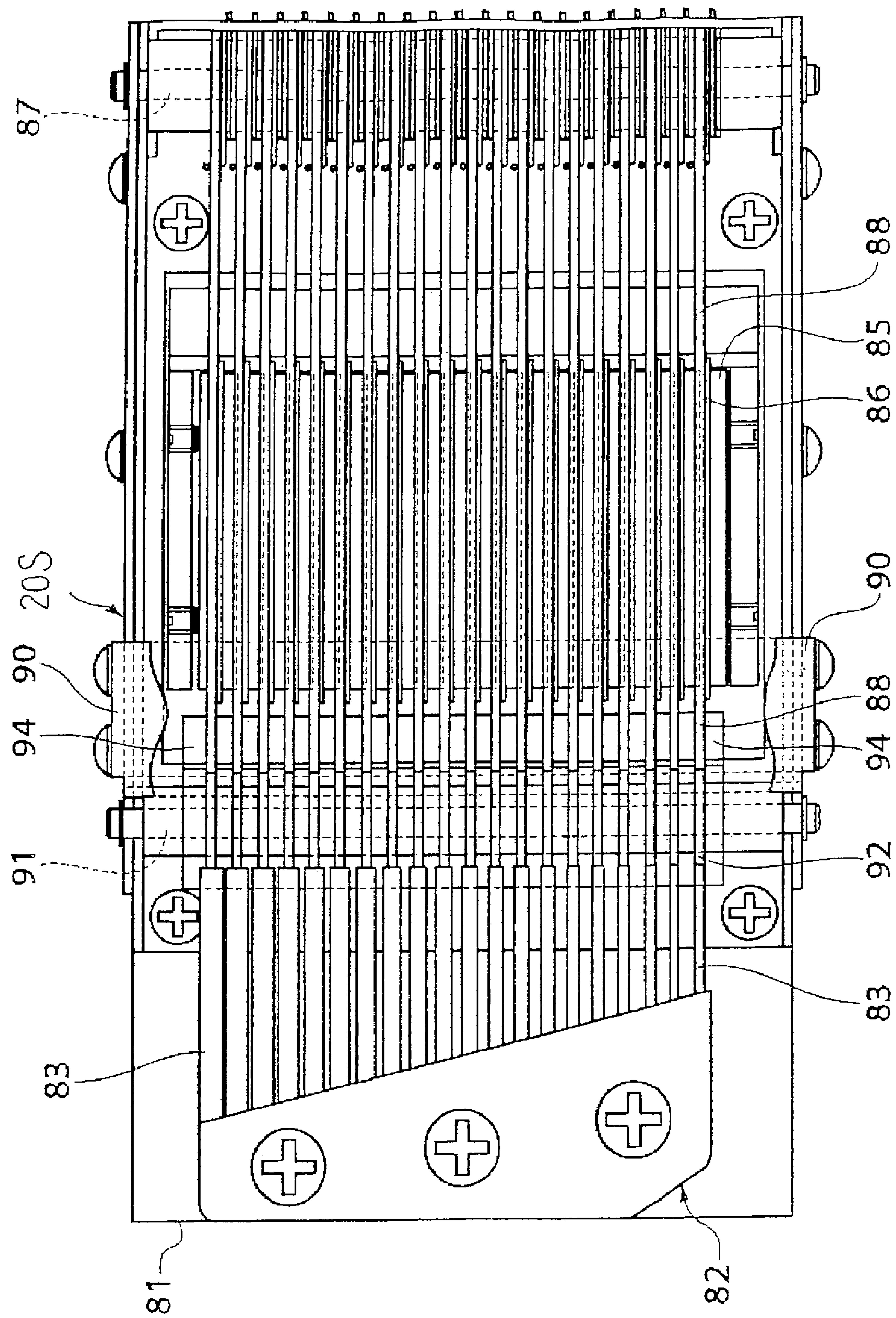


Fig. 51

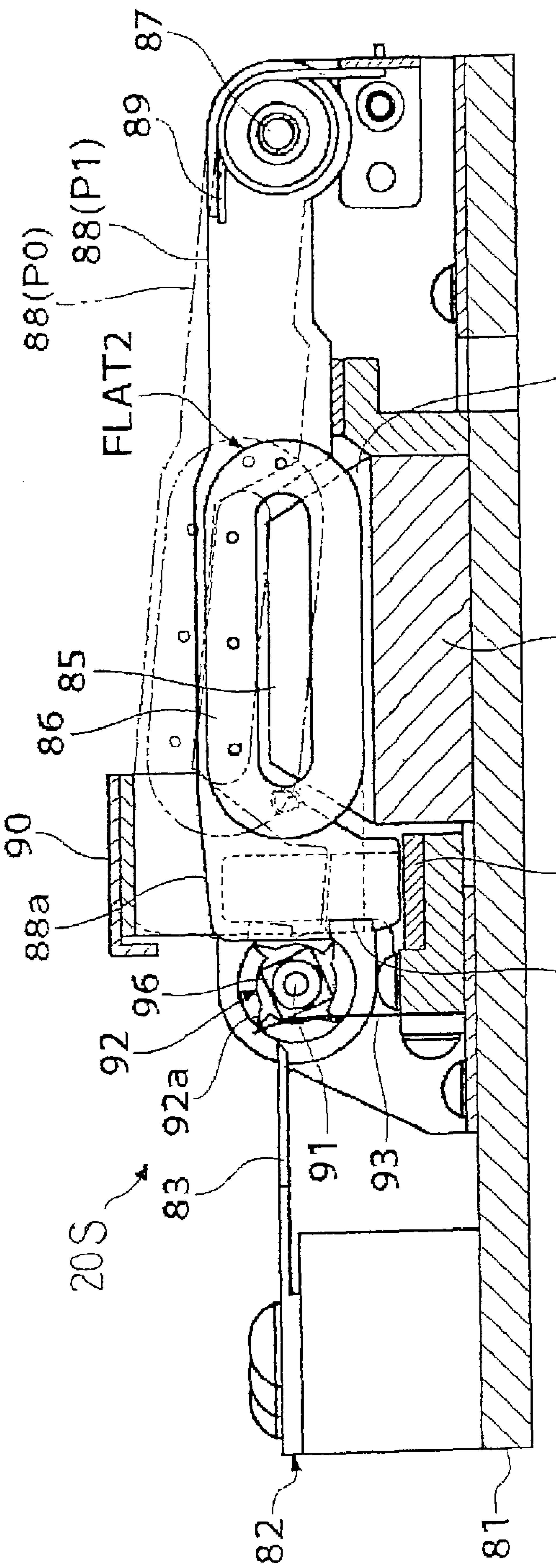


Fig.52A

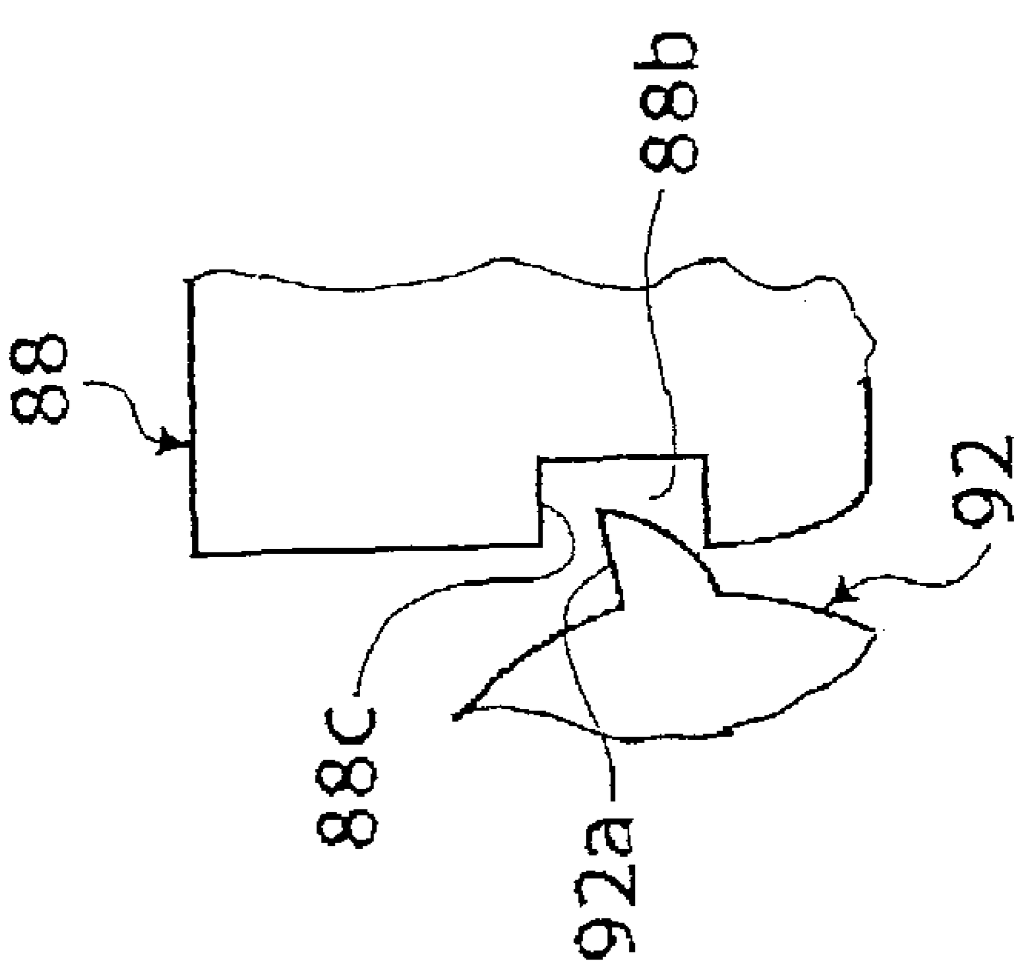


Fig.52C

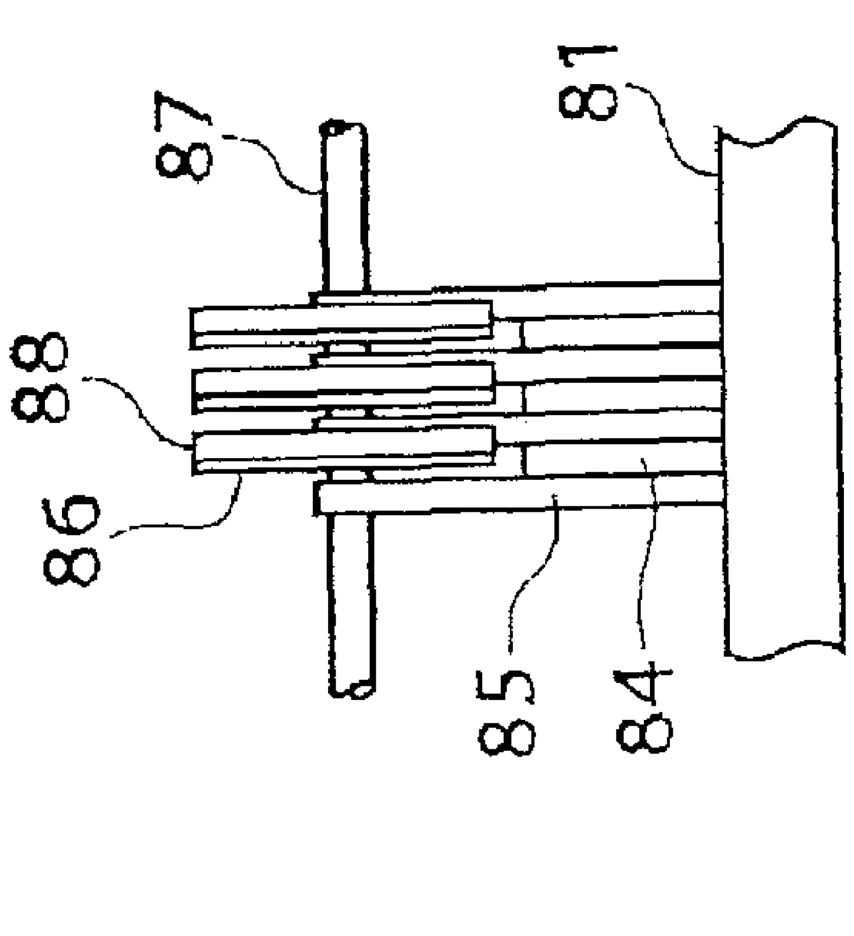


Fig.52B

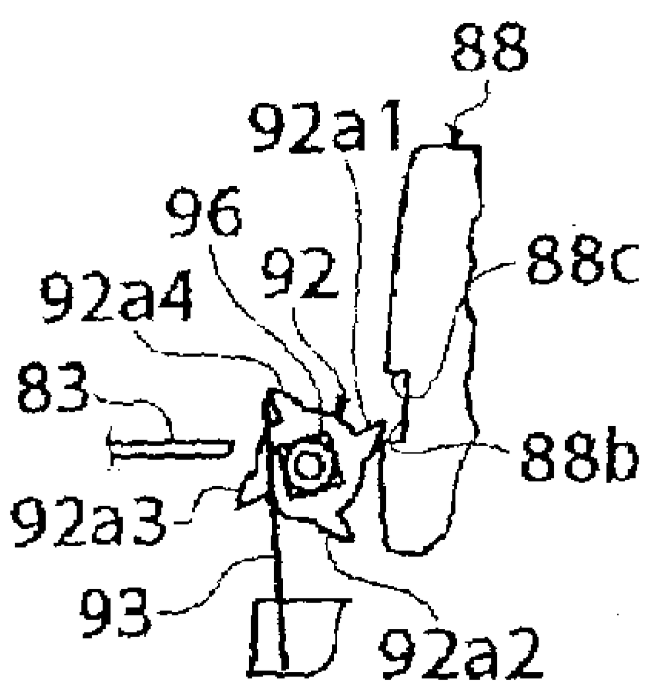


Fig.53A

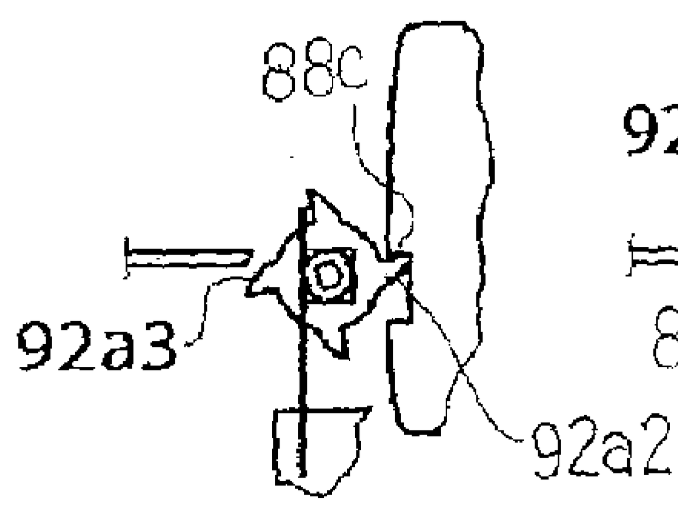


Fig.53B

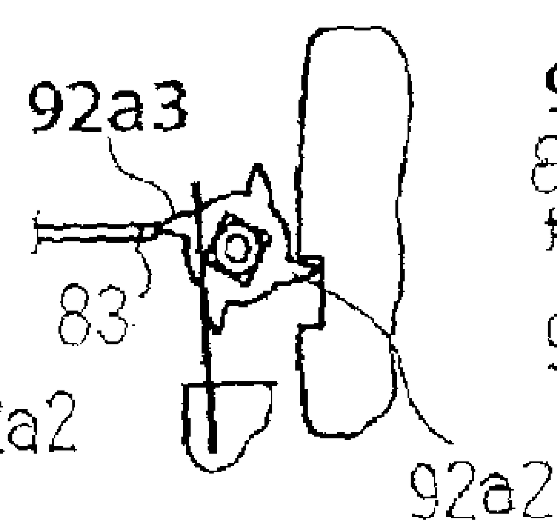


Fig.53C

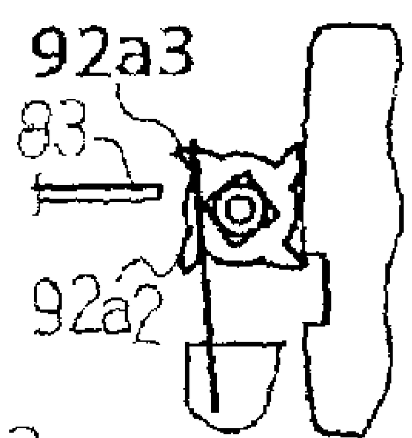


Fig.53D

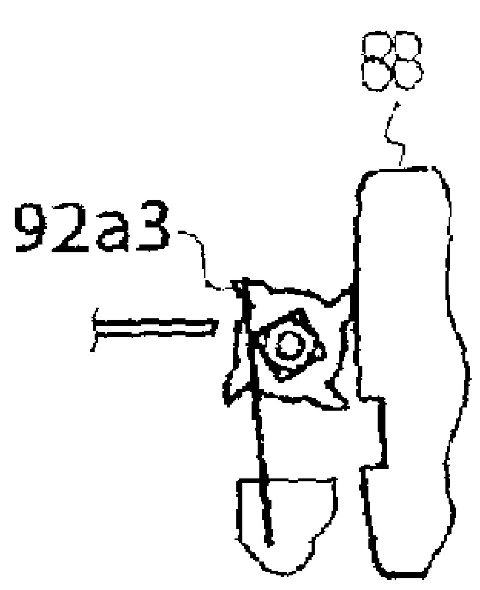


Fig.53E

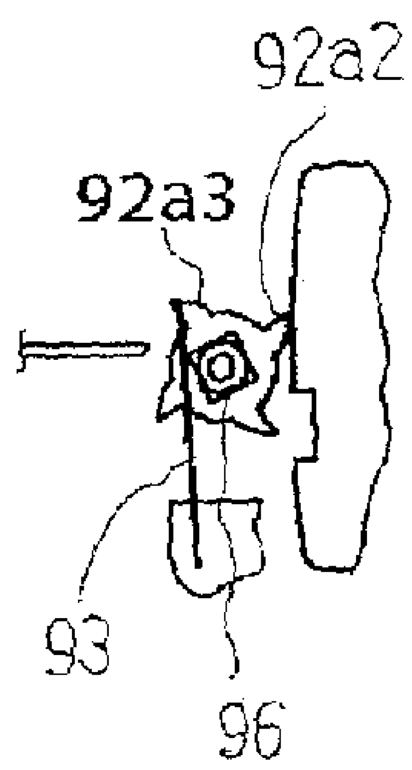


Fig.53F

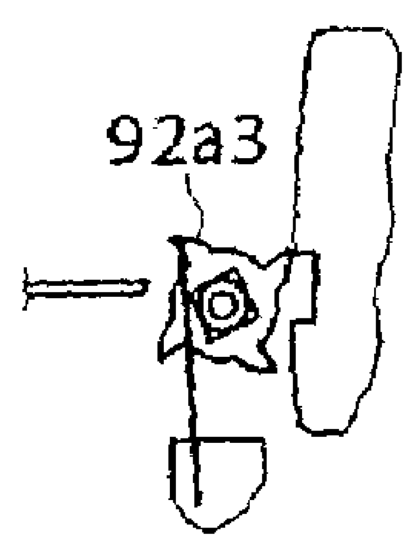


Fig.53G

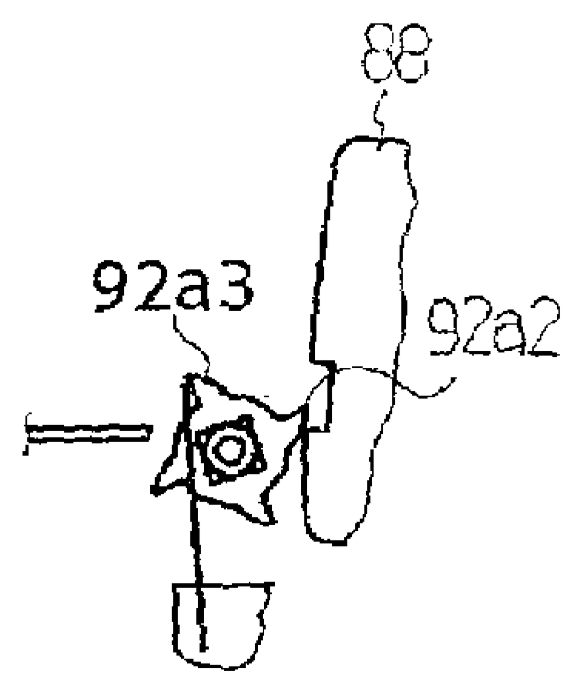


Fig.53H

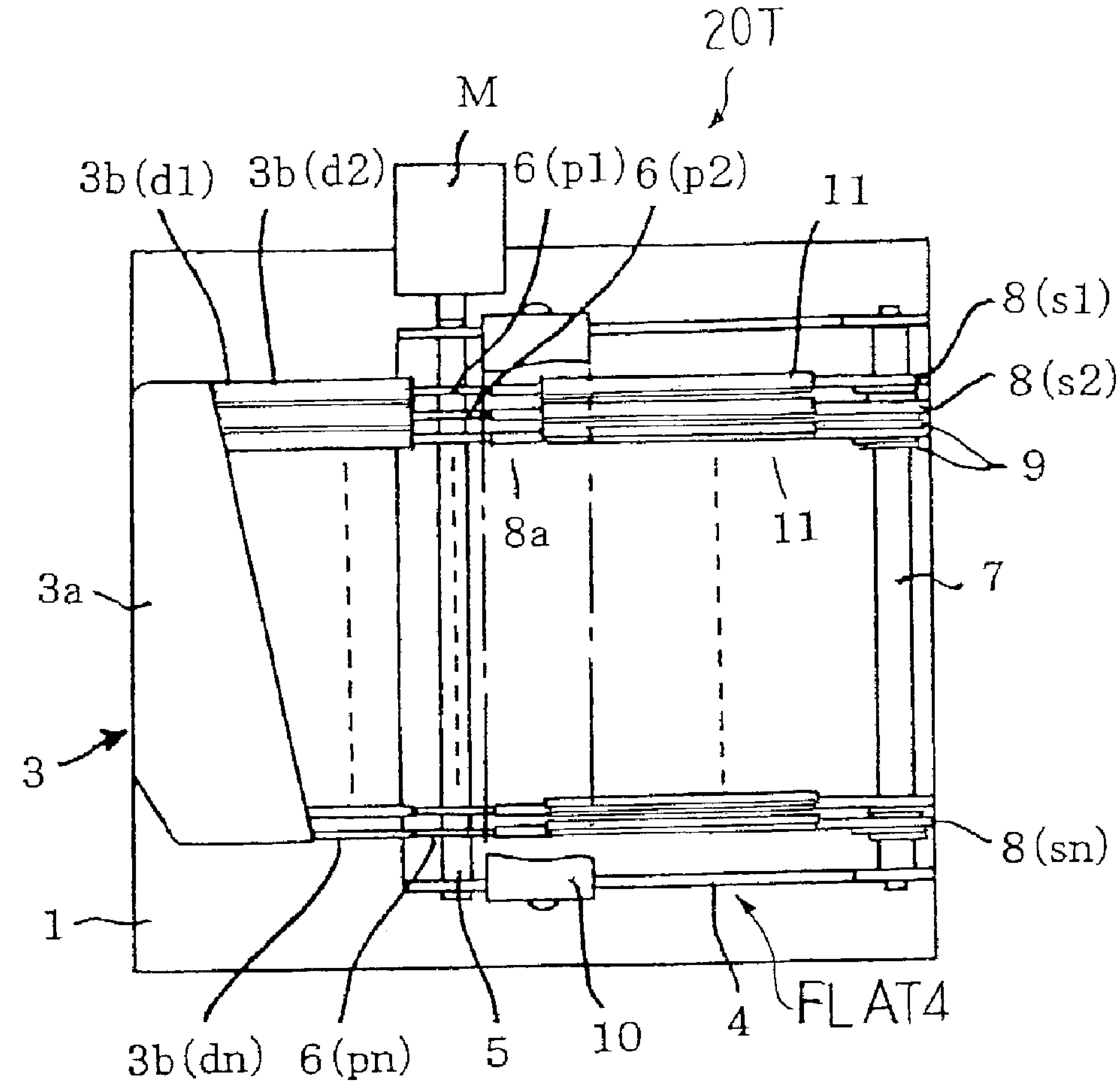

20T
M
3b(d1)
3b(d2)
6(p1)
6(p2)
11
8(s1)
8(s2)
9
8a
11
7
3a
3
1
8(sn)
3b(dn)
6(pn)
5
10
4
FLAT4

Fig. 54

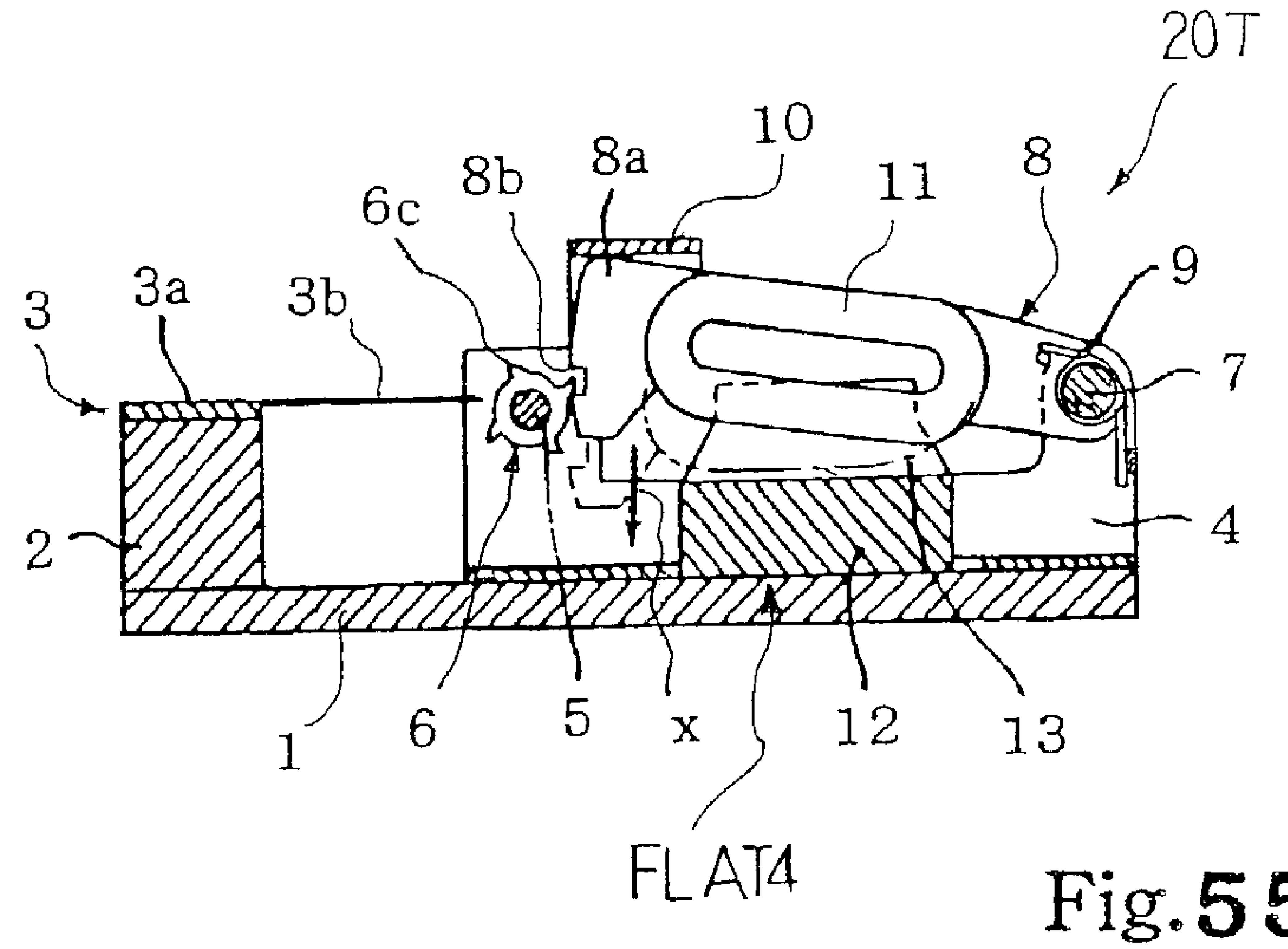

20T
10
8b
8a
11
8
6c
9
3
3a
3b
7
2
4
1
6
5
x
12
13
FLAT4

Fig. 55

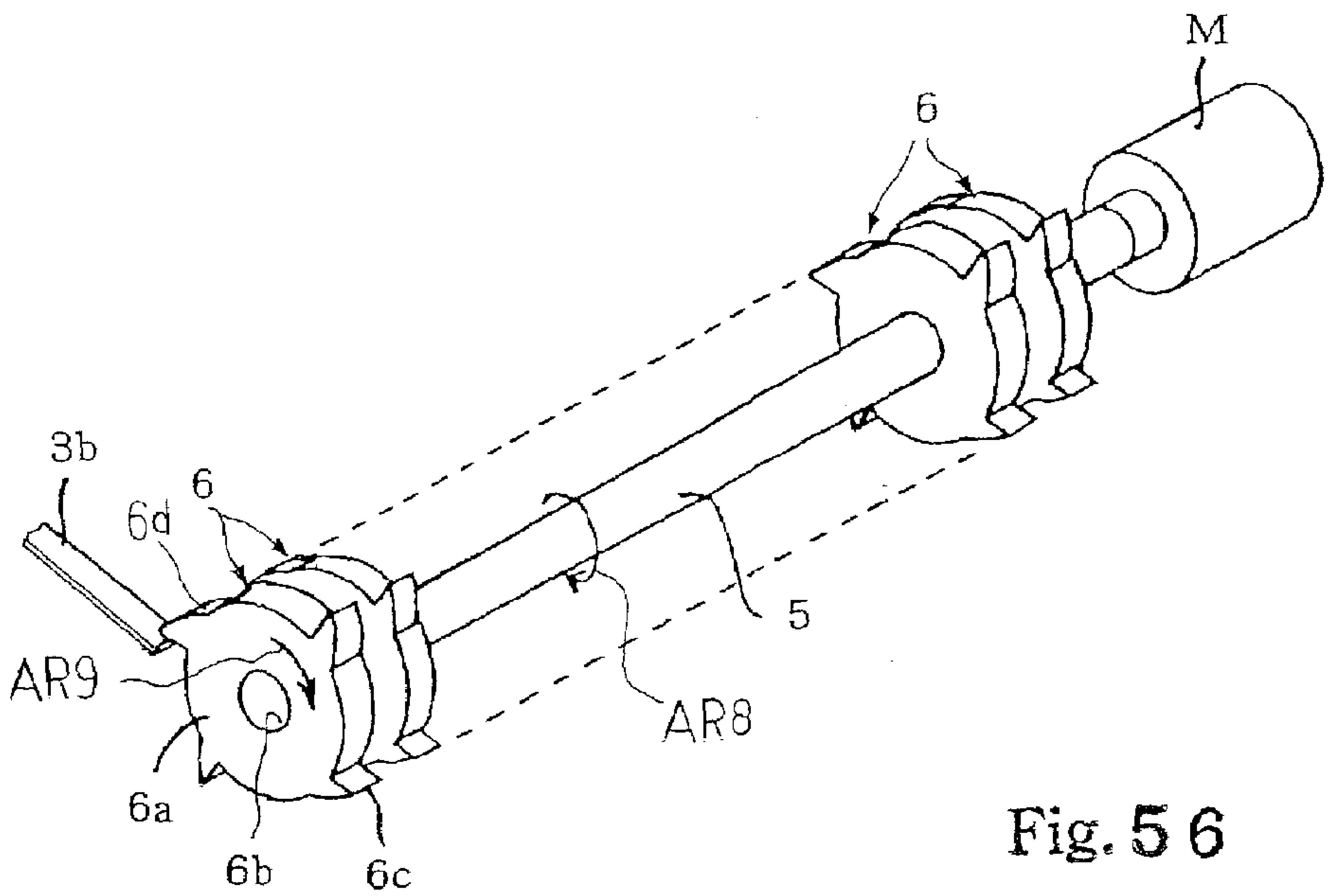

M
6
3b
6d
6
5
AR9
AR8
6a
6b
6c

Fig. 56

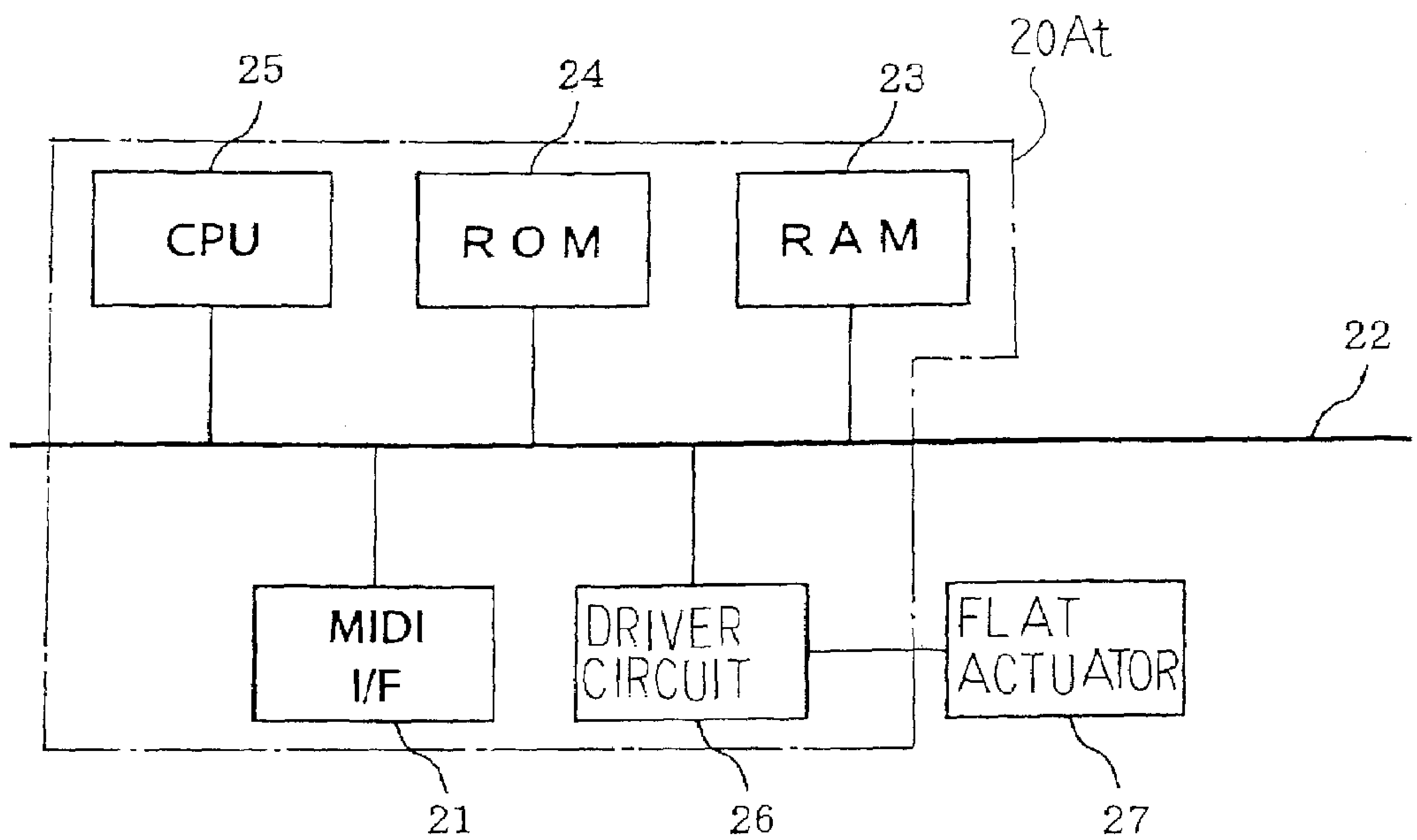

20At
25
24
23
CPU
ROM
RAM
22
MIDI
I/F
DRIVER
CIRCUIT
FLAT
ACTUATOR
21
26
27

Fig. 57

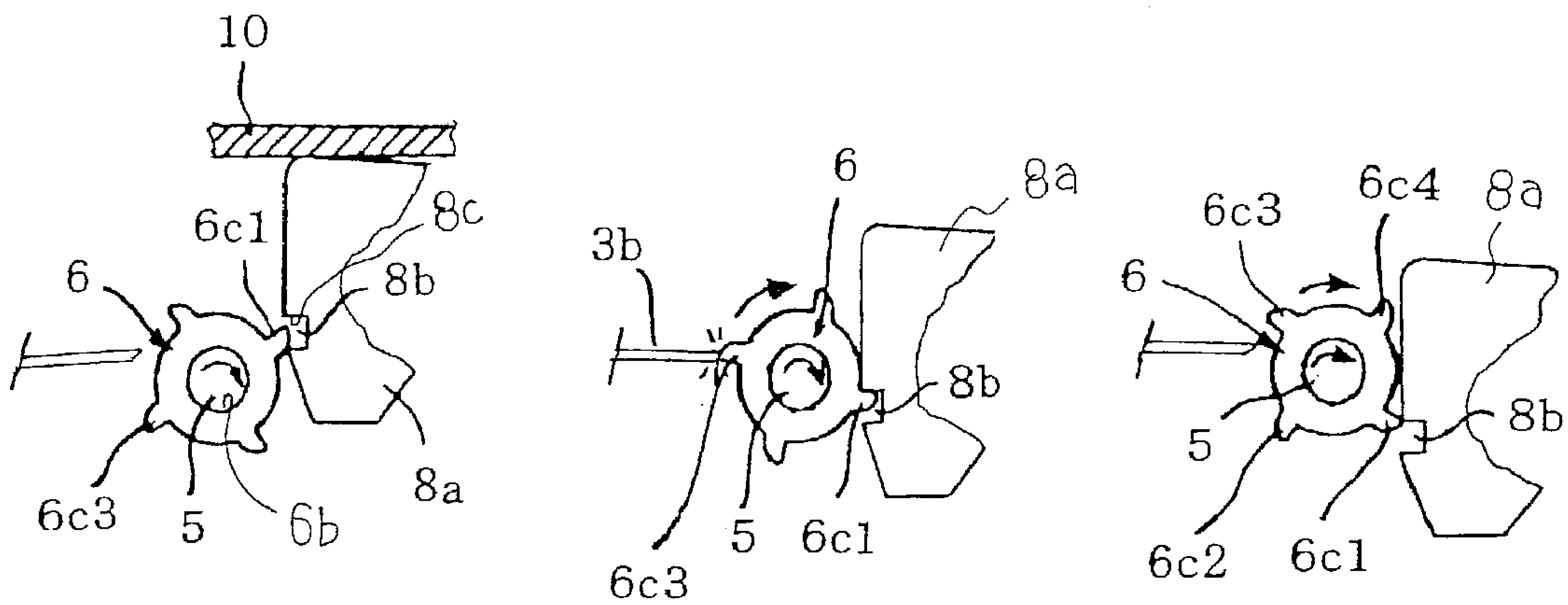


Fig. 58A Fig. 58B Fig. 58C

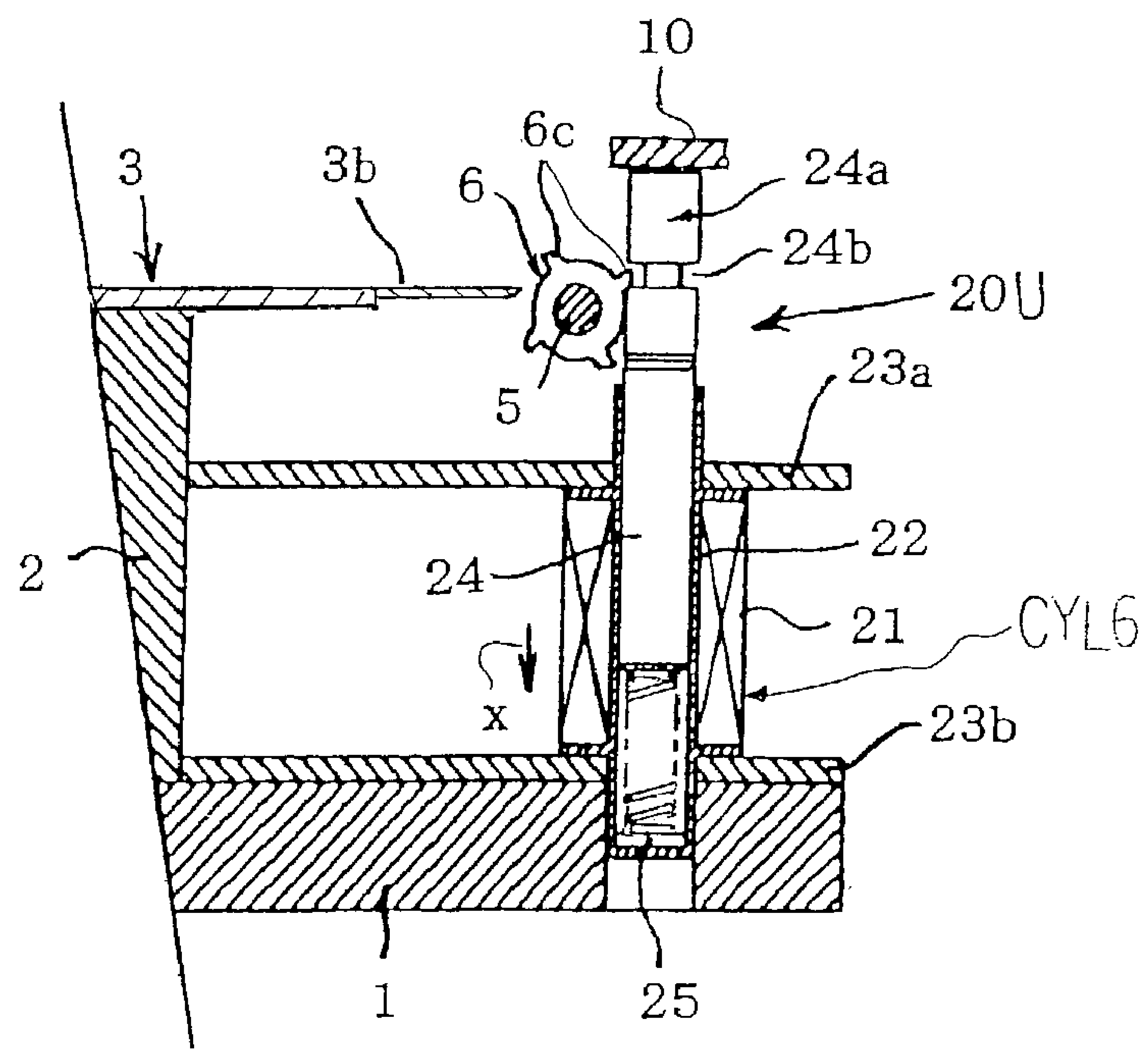


Fig. 59

COMPACT MUSICAL INSTRUMENT EQUIPPED WITH AUTOMATIC PLAYER

FIELD OF THE INVENTION

This invention relates to a musical instrument and, more particularly, to a musical instrument equipped with an automatic player such as, for example, a music box.

DESCRIPTION OF THE RELATED ART

A music box is a typical example of the musical instrument with a built-in automatic player. A standard music box is broken down into a tone generator and an automatic player. The tone generator is implemented by an array of plural reeds, and the reeds vibrate for generating tones when the automatic player selectively plucks them. The tones are different in pitches from one another. The plural reeds may be formed into a comb-like reed unit. On the other hand, the automatic player is implemented by a rotational barrel drum. The rotational barrel drum is formed with small projections over the outer surface thereof, and the small projections are fixed to the outer surface. In other words, users can not relocate the small projections. The rotational barrel drum is provided in the close proximity of the array of reeds, and the barrel drum is driven for rotation over a certain angle equal to or less than 360 degrees. While the barrel drum is rotating, the small projections are selectively brought into contact with the reeds, and pluck the reeds. The reeds vibrate for generating the tones. Thus, the automatic player performs a piece of music through the vibrations of the reeds.

Each reed is doubled in another sort of tone generator, and the small projection concurrently plucks the double reed for generating a tone. The vibrating double reed makes the tone richer the tone generated from the single reed. The other features are similar to those of the standard music box. A barrel drum is formed with small projections, and is provided in the close proximity of the set of double reeds. While the barrel drum is rotating, the small projections selectively pluck the double reeds for performing a piece of music. However, the projections are fixed to the outer surface of the barrel drum. This means that the user can not relocate the small projections.

A problem inherent in the prior art standard music boxes is poor flexibility. The barrel drums are designed for particular pieces of music. Even if the user wishes to make the prior art standard music box perform another piece of music, the prior art standard music box can not respond to the user's request. Only one way to respond the user's request is to suggest the user to replace the barrel drum with a new barrel drum designed for the other piece of music.

The poor flexibility is because of the small projections fixed to the outer surface of the barrel drum. If the small projections are easily relocated, the standard music box can selectively play pieces of music without any replacement of the barrel drum. From this viewpoint, several music boxes have been proposed.

One of the music boxes selectively performing pieces of music on demand includes the tone generator, which is also implemented by an array of reeds, and an automatic player with a complex mechanism. The reeds are arranged in a row on a virtual straight line. The automatic player includes a turn-table, plural solenoid-operated actuators, hammers and a controlling circuit. The hammers are provided in association with the reeds for striking the associated reeds, and are rotatably supported by a frame like levers. Although the reeds are quite thin, the hammers are arranged along an arc, and the hammers strike the reeds at the inner ends thereof. This feature is desirable, because the large-sized hammers are arrayed. The large-sized hammers are durable.

The turn-table has an axis of rotation vertical to the array of reeds so that the rotating surface of the turn-table is maintained in parallel to the array of reeds. The solenoid-operated actuators are fixed to the turn-table, and the controlling circuit selectively supplies driving current to the solenoid-operated actuators. The solenoid-operated actuators retract the plungers into the associated solenoids in the absence of the driving current. Even though the turn table is rotated, the plungers do not kick the hammers, and, accordingly, the hammers never strike the reeds.

When the user requests the automatic player to perform a piece of music, the turn-table is driven for rotation, and the controlling circuit starts to selectively supply the driving current to the solenoid-operated actuators. The solenoid-operated actuators sequentially project the plungers in the presence of the driving current, and the plungers kick the associated hammers. Then, the hammers strike the associated reeds, and give rise to vibrations of the reeds. The reeds generate the tones for performing the piece of music.

The user is assumed to request the automatic player to perform another piece of music. The controlling circuit changes the sequence of the solenoid-operated actuators to be energized with the driving current. The controlling circuit starts to supply the driving current to the solenoid-operated actuators, and the hammers strike the reeds in the different order. This results in the other piece of music. This music box is hereinafter referred to as "first prior art music box".

Another music box selectively performing pieces of music on demand is also broken down into the tone generator, which is implemented by an array of reeds, and an automatic player. The reeds are arranged in a single row on a virtual straight line. The automatic player includes a rotational cylinder, pins, solenoid-operated actuators and a controlling circuit. The rotational cylinder has an axis of rotation, which is in parallel to the array of reeds. Through-holes are formed in the cylinder, and the pins are received in the through-holes. The pins are projectable from and retractable into the through-holes. The solenoid-operated actuators are accommodated in the cylinder, and push and pull the associated pins. The controlling circuit is electrically connected to the solenoid-operated actuators, and selectively supplies driving current to the solenoid-operated actuators. The reeds are respectively aligned with the orbits of the pins. While the solenoid-operated actuators are keeping the pins retracted into the through-holes, the reeds are spaced from the outer surface of the cylinder, and any reed is not plucked. When the controlling circuit energizes a solenoid-operated actuator, the solenoid-operated actuator makes the associated pin project from the through-hole, and the pin plucks the associated reed.

A user is assumed to request the automatic player to perform a piece of music, the controlling circuit searches the data storage for a set of pieces of music data, and sequentially supplies the driving current to the solenoid-operated actuators in accordance with the pieces of music data. The solenoid-operated actuators project pins and retract the pins so that the reeds are selectively plucked for generating the tones along the piece of music. If the user requests the automatic player to perform another piece of music, the controlling circuit changes the sequence of the solenoid-operated actuators to be energized, and the pins plucks the reeds in the different order. This music box is hereinafter referred to as "second prior art music box".

Yet another music box selectively performing pieces of music on demand is also broken down into a tone generator and an automatic player. The tone generator is also implemented by an array of reeds. The reeds are arranged in a single row on a virtual straight line. A plurality of driving units form in combination the automatic player together with a controller, and give rise to vibrations in the associated reeds, respectively. Each of the driving unit includes a solenoid-operated actuator, an arm and a variable rod. The arm is rotatably supported by a frame, and is engaged with the solenoid-operated actuator and variable rod at different portions. When the solenoid-operated actuator is energized, the arm is driven for rotation, and pushes down the variable rod. Then, the reed is warped. The variable rod laterally escapes from the reed, and the reed starts to vibrate for generating the tone. The variable rod returns to the initial position, and gets ready to push the reed, again. Thus, the variable rod does not interfere with the vibrations in the associated reed. The sequence of the solenoid-operated actuators to be energized is changeable so that the automatic player selectively performs pieces of music without change of the component parts. This music box is hereinafter referred to as "third prior art music box".

Still another music box selectively performing pieces of music on demand comprises a comb and an automatic player The teeth of the comb are arranged in a single row on a virtual straight line, and are vibratory at different pitches. The automatic player includes star wheels respectively associated with the teeth, a solenoid-operated actuator, a conveyer and a controlling circuit. The solenoid-operated actuator is attached to the conveyer, and the conveyer moves the solenoid-operated actuator in a direction parallel to the row of the teeth. The star wheels are selectively driven for rotation by the solenoid-operated actuator, and pluck the associated teeth for generating the tones. When the user requests the automatic player to perform a piece of music, controlling circuit starts the conveyer quickly to move the solenoid-operated actuator. The controlling circuit sequentially stops the solenoid-operated actuator at the star wheels associated with the teeth to be plucked, and energizes the solenoid-operated actuator. The solenoid-operated actuator gives rise to the rotation of the selected star wheels so that the star wheels pluck the associated teeth for generating the tones. This music box is hereinafter referred to as "fourth prior art music box".

However, the flowing problems are encountered in those prior art music boxes. The first prior art music box is bulky. This is because of the fact that the automatic player requires a lot of rotatably supported hammers equal in number to the reeds for generating the tones. Moreover, it is difficult to concurrently drive more than one hammer for a chord.

The second prior art music box can merely perform several pieces of music. The through-holes formed in the cylinder and the rotating speed set the limit on the pieces of music to be performed. The controller can change the sequence of the pins to be driven from a combination of the through-holes to another combination of the through-hole. Another problem inherent in the second prior art music box is poor design flexibility. The relative position between the array of reeds and the rotational cylinder is hardly changed so that the designer merely modifies the other parts. Yet another problem inherent in the second prior art music box is poor durability. The solenoid-operated actuators and pins are complicatedly accommodated in the narrow inner space defined in the rotational cylinder. The complicated mechanism is liable to have troubles. The users can not cope with the mechanical troubles, and are discarded without repair.

The third prior art music box is also bulky, and the tones are not clear. These problems are derived from the action of the variable rods. When the automatic player generates a tone, the variable rod is pushed downwardly so as to warp the reed. When the variable rod escapes from the warped reed, the reed vibrates. In order to permit the variable rods, which are equal in number to the reeds, to escape from the reeds and return to the initial positions, hollow space is required in the vicinity of the reeds. The hollow space makes the third prior art music box bulky. The vibrations take place at the escape of the variable rod. In other words, the reeds start the vibrations from the warped state. This is unnatural, and the tones are less clear.

The fourth prior art music box is also bulky. The conveyer is required for moving the solenoid-operated actuator along the array of teeth, and a suitable mechanism is further required for making the star wheels to the initial positions. These components occupy wide space, and makes the fourth prior art music box bulky.

SUMMARY OF THE INVENTION

It is therefore an important object of the present invention to provide a compact musical instrument, which is equipped with an automatic player for selectively performing pieces of music.

It is also an important object of the present invention to provide a musical instrument, which is equipped with an automatic player with a simple structure for performing a piece of music.

It is another important object of the present invention to provide a musical instrument, which is equipped with an automatic player for generating clear tones.

In accordance with one aspect of the present invention, there is provided a musical instrument comprising a tone generator having vibratory members radially arranged with respect to a center of the tone generator, and an automatic player selectively generating vibrations of said vibratory members for producing tones different in pitch from one another through the vibrations and including player's fingers arranged in the proximity of outer ends of the vibratory members and a controller connected to the player's fingers for selectively actuating the player's fingers on the basis of pieces of music data variable without changing a physical structure of the controller.

In accordance with another aspect of the present invention, there is provided a musical instrument comprising a tone generator having an array of vibratory members for generating tones different in pitch from one another through vibrations and an automatic player including player's fingers for selectively generating the vibrations in the vibratory members and a controller connected to the player's fingers for selectively actuating the player's fingers on the basis of pieces of music data variable without changing a physical structure of the controller, and each of the player's fingers has a rotary vibration generator rotatably supported by a stationary member in the proximity of associated one of the vibratory members for generating the vibrations through rotation thereof and an actuator connected to the controller and selectively energized by the controller for rotating the rotary vibration generator.

In accordance with yet another aspect of the present invention, there is provided a musical instrument comprising a tone generator having an array of vibratory members for generating tones different in pitch from one another through vibrations and an automatic player including player's fingers for selectively generating the vibrations in the vibratory members and a controller connected to the player's fingers for selectively actuating the player's fingers on the basis of pieces of music data variable without changing a physical structure of the controller, and each of the player's fingers includes a vibration generator moved from a rest position along a first path for generating the vibrations in associated one of the vibratory members and a second path for returning to the rest position, an actuator connected to the controller and moving the vibration generator along the first path and the second path and a route changer connected to the vibration generator for guiding the vibration generator to the second path after generating the vibrations so as to permit the associated vibratory member to freely vibrate without any interference due to the vibration generator passing beside the associated vibratory member along the second path.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the musical instrument with the automatic player will be more clearly understood from the following description taken in conjunction with the accompanying drawings, in which

FIG. **1**A is a schematic plane view showing the layout of a tone generator and an automatic player incorporated in a music box according to the present invention,

FIG. **1**B is a cross sectional view taken along line A—A of FIG. **1**A and showing the structure of the music box,

FIG. **2**A is a plane view showing a reed and a player's finger of an automatic player incorporated in the music box,

FIG. **2**B is a cross sectional view taken along line B—B and showing the structure of the player's finger,

FIG. **3** is a block diagram showing the system configuration of a controller,

FIGS. **4**A to **4**C are schematic views showing the player's finger plucking the associated reed,

FIG. **5** is a cross sectional view showing the player's finger after the plucking,

FIGS. **6**A to **6**D are perspective views showing the external appearance of the music box and modifications thereof,

FIGS. **7**A and **7**B are cross sectional views showing other modifications of the music box implementing the first embodiment,

FIG. **8**A is a perspective view showing the structure of a tone generating unit incorporated in another modification of the music box,

FIG. **8**B is a schematic view showing the arrangement of the tone generating units,

FIG. **9**A is a plane view showing strings and automatic player incorporated in another modification of the music box,

FIG. **9**B is a cross sectional view taken along line C—C of FIG. **9**A and showing the structure of the modification,

FIG. **10**A is a schematic plane view showing the layout of a tone generator and an automatic player incorporated in a musical instrument according to the present invention,

FIG. **10**B is a cross sectional view taken along line A1—A1 of FIG. **10**A and showing the structure of the music box,

FIG. **11**A is a plane view showing a reed and a player's finger of an automatic player incorporated in the music box,

FIG. **11**B is a cross sectional view taken along line B1—B1 of FIG. **11**A and showing the structure of the player's finger,

FIG. **12** is a block diagram showing the system configuration of a controller incorporated in the automatic player,

FIG. **13** is a cross sectional view showing the player's finger after the plucking,

FIG. **14** is a cross sectional view showing a player's finger incorporated in a modification of the musical instrument,

FIG. **15**A is a perspective view showing a player's finger incorporated in another modification of the musical instrument,

FIG. **15**B is a perspective view showing a pick incorporated in the player's finger,

FIG. **15**C is a perspective view showing paths formed in a guide block also incorporated in the player's finger,

FIG. **15**D is a cross sectional view in a direction of F**5** of FIG. **15**C and showing the paths.

FIG. **15**E is a schematic cross sectional view showing a pick attached to a solenoid-operated actuator incorporated in the player's finger,

FIG. **15**F is a front view showing the pick attached to the solenoid-operated actuator,

FIG. **16** shows a block diagram showing the system configuration of a controller incorporated in another musical instrument according to the present invention,

FIG. **17** is a perspective view showing player's fingers incorporated in the musical instrument,

FIG. **18**A is a side view showing the player's finger before plucking the associated reed,

FIG. **18**B is a rear view showing the player's finger,

FIG. **19** is a side view showing the player's finger after the plucking,

FIG. **20**A is a side view showing another player's finger incorporated in a musical instrument according to the present invention,

FIG. **20**B is a rear view showing the player's finger,

FIG. **21** is a plane view showing the layout of reeds and player's fingers incorporated in a musical instrument according to the present invention,

FIG. **22**A is a cross sectional view taken along line C—C of FIG. **21** and showing the structure of the musical instrument,

FIG. **22**B is a plane view showing a standard solenoid-operated actuator,

FIG. **22**C is a view a rotary pick and a brake unit viewed in a direction indicated by F**1**,

FIGS. **23**A to **23**H are schematic views illustrating a plucking motion of the rotary pick,

FIG. **24** is a plane view showing the layout of a musical instrument according to the present invention,

FIG. **25**A is a cross sectional view showing the structure of the musical instrument,

FIG. **25**B is a front view showing swingable arms and solenoid-operated flat actuators,

FIG. **25**C is a schematic side view showing the swingable arm and an associated rotary pick,

FIG. **26**A is a plane view showing another musical instrument according to the present invention,

FIG. **26**B is a cross sectional view showing the structure of a player's finger incorporated in the musical instrument,

FIG. **27**A is a plane view showing the layout of another musical instrument according to the present invention,

FIG. **27**B is a rear view showing the structure of the musical instrument on the left side,

FIG. **28** is a perspective view showing a player's finger incorporated in the musical instrument,

FIG. **29**A is a side view showing the player's finger,

FIG. **29**B is a side view showing the parts encircled in EX**1** of FIG. **29**A,

FIGS. **30**A and **30**B are side views showing a modification of the player's finger shown in FIG. **28**,

FIG. 30C is a side view showing another modification of the player's finger,

FIG. 31 is a block diagram showing the system configuration of a controller incorporated in another musical instrument according to the present invention,

FIG. 32 is a perspective view showing the structure of a player's finger incorporated in the musical instrument,

FIG. 33A is a side view showing the player's finger before plucking,

FIG. 33B is a rear view showing the player's finger,

FIG. 34 is a side view showing the player's finger after the plucking,

FIG. 35A is a side view showing another player's finger incorporated in a musical instrument according to the present invention,

FIG. 35B is a rear view showing the player's finger,

FIG. 36 is a plane view showing the layout of reeds and player's fingers incorporated in another musical instrument according to the present invention,

FIG. 37A is a cross sectional view taken along line C—C of FIG. 36 and showing the structure of the musical instrument,

FIG. 37B is a plane view showing a standard solenoid-operated actuator,

FIG. 37C is a view a rotary pick and a brake unit viewed in a direction indicated by F1 in FIG. 37B,

FIGS. 38A to 38H are schematic views illustrating a plucking motion of the rotary pick,

FIG. 39 is a plane view showing the layout of another musical instrument according to the present invention,

FIG. 40A is a cross sectional view showing the structure of the musical instrument,

FIG. 40B is a front view showing swingable arms and solenoid-operated flat actuators,

FIG. 40C is a schematic side view showing the swingable arm and an associated rotary pick,

FIG. 41A is a plane view showing a musical instrument according to the present invention,

FIG. 41B is a cross sectional view showing the structure of player's fingers incorporated in the musical instrument according to the present invention,

FIG. 42A is a rear view showing the structure of another musical instrument on the left side,

FIG. 42B is a plane view showing the layout of the musical instrument according to the present invention,

FIG. 43 is a perspective view showing a player's finger incorporated in the musical instrument,

FIG. 44A is a side view showing the player's finger,

FIG. 44B is a side view showing the parts encircled in EX1 of FIG. 44A,

FIGS. 45A and 45B are side views showing a modification of the player's finger shown in FIG. 43,

FIG. 45C is a side view showing another modification of the player's finger,

FIG. 46 is a block diagram showing the system configuration of a controller incorporated in another musical instrument according to the present invention,

FIG. 47 is a perspective view showing the structure of a player's finger incorporated in the musical instrument,

FIG. 48A is a side view showing the player's finger before plucking,

FIG. 48B is a rear view showing the player's finger,

FIG. 49 is a side view showing the player's finger after the plucking,

FIG. 50A is a side view showing another player's finger incorporated in a musical instrument according to the present invention,

FIG. 50B is a rear view showing the player's finger,

FIG. 51 is a plane view showing the layout of another musical instrument according to the present invention,

FIG. 52A is a cross sectional view showing the structure of the musical instrument,

FIG. 52B is a front view showing swingable arms and solenoid-operated flat actuators,

FIG. 52C is a view a rotary pick and a brake unit viewed in a direction indicated by F1 in FIG. 52B,

FIGS. 53A to 53H are schematic views illustrating a plucking motion of the rotary pick,

FIG. 54 is a plane view showing the layout of another musical instrument according to the present invention,

FIG. 55 is a cross sectional view showing the structure of the musical instrument,

FIG. 56 is a perspective view showing an array of rotary picks,

FIG. 57 is a block diagram showing the system configuration of a controller,

FIGS. 58A to 58C are schematic views showing the rotary pick plucking an associated reed, and

FIG. 59 is a cross sectional view showing a modification of the musical instrument.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

Prototype

Referring to FIGS. 1A and 1B of the drawings, a music box embodying the present invention largely comprises a housing 1, a tone generator 3 and an automatic player 5. A hollow space is defined in the housing 1, and the tone generator 3 and automatic player 5 are placed inside the housing 1. The tone generator 3 occupies a central zone of the hollow space, and the automatic player 5 is disposed in the peripheral zone of the hollow space, i.e., around the tone generator 3. The automatic player 5 drives the tone generator without changing its position so that any additional space is not required for the automatic player. This results in the compact music box.

In the following description, a direction from the central zone toward the peripheral zone is "outward direction", and a direction from the peripheral zone to the central zone is "inward direction".

A bottom disk 10 and a cap 16 form in combination the housing 1. The cap 16 defines a recess, and the depth of the recess is greater than the thickness of the bottom desk 10. For this reason, when the cap 16 and bottom disk 10 are assembled into the housing 1, the inner space takes place in the housing 1, and the tone generator 3 and the automatic player 5 are accommodated therein.

The tone generator 3 includes a pedestal 31 and a daisy reed wheel 32. The pedestal 31 has a column shape, and is upright on the central area of the upper surface of the bottom disk 10. The daisy reed wheel 32 has a boss portion 33*a* and reeds 33*b*. The boss portion 33*a* is fixed to the upper surface of the pedestal 31, and is horizontally maintained. The reeds 33*b* radially project from the periphery of the boss portion 33*a*, and reach the boundary between the central zone and the peripheral zone. In this instance, twenty-four reeds 33*b* project from the boss portion 33*a* at regular intervals. Although the reeds 33*b* are different in length and width from one another, the tips 33*c* of the reeds 33*b* reaches a virtual circle concentric with the boss portion 33*a*. This means that the boss portion **33***a* has the radius increased together with the angle. For this reason, the periphery of the boss portion **33***a* is like an involute line. The reeds **33***b* are vibratory at predetermined values of the frequency so that the vibrating reeds **33***b* generate the tones of a scale, respectively.

The daisy reed wheel **32** is desirably for the automatic player **5**, because the tips **33***c* are widely spaced from one another along the boundary between the central zone and the peripheral zone. The automatic player **5** includes player's fingers **20**, which are provided around the daisy reed wheel **32** at regular intervals. The player's fingers **20** are respectively associated with the reeds **33***b*, and are selectively energized for plucking the reeds **33***b*. In this instance, twenty-four player's fingers **20** are disposed on the bottom disk **10**. Since the tips **33***c* are widely spaced, a wide local space is assigned to each of the player's fingers **20**. When the player's fingers **20** pluck the associated reeds **33***b*, the reeds **33***b* vibrate for generating the tones. Thus, the automatic player **5** performs a piece of music or a passage of the piece of music.

Turning to FIGS. **2**A, **2**B and **3**, the automatic player **5** includes the player's fingers **20** and a controller **20**A. The player's fingers **20** are similar in structure to one another, and one of the player's fingers **20** is hereinafter described in detail with reference to FIGS. **2**A and **2**B. The controller **20**A is connected to the player's fingers **20** in parallel, and selectively supplies driving current to the player's fingers **20**.

The player's finger **20** is broken down into a solenoid-operated actuator **21**, a pick **22** and a spring **25**. The solenoid-operated actuator **21** is supported by a bottom yoke **25***a*, which in turn is supported by the bottom disk **10**, and the pick **22** is mounted on the solenoid-operated actuator **21**. The spring **25** is connected between the pick **22** and the bottom yoke **25***a*, and urges the pick **22** outwardly.

A coil **21***a*, a bobbin **23**, a cushion sheet **23**, a top yoke **25***b*, an additional yoke **25***c* and a plunger **26** form in combination the solenoid-operated actuator **21**. The bobbin **23** has a cylindrical configuration, and the cushion sheet **23***a* is provided at the bottom of the inner space of the bobbin **23**. The coil **21** is wound on the outer surface of the bobbin **23**, and the plunger **26** is slidably received in the inner space of the bobbin **23**. The bottom yoke **25** has an inner portion slightly projecting, and forms an offset yoke structure. When current flows through the coil **21***a*, the current creates a magnetic field across the bobbin **23**. The bobbin **23** and bottom yoke **25***a* offer a magnetic path to the electric field. The bottom yoke **25***a* has the inner portion projecting from the outer portion so that the magnetic field is asymmetrically developed. For this reason, the picks **22** are urged inwardly as indicated by arrow **AR1**, and the plunger **26** upwardly projects from the bobbin **23**. The inwardly inclined pick **22** is brought into contact with the tip **33***c* of the associated reed **33***b*. If the magnetic field is removed, then the plunger **26** is retracted into the bobbin **23**, and is landed on the cushion sheet **23***a*. The cushion sheet **23***a* prevents the plunger **26** from dropping out.

The plunger **26** is formed with a pair of wall portions **27**. The wall portions **27** are upright on the upper surface of the plunger **26**, and are spaced from each other in parallel to the associated reed **33***b*. A pin **24** is fixed at both ends thereof to the wall portions **27** in such a manner as to be perpendicular to the longitudinal direction of the associated reed **33***b*, and the pick **22** is rotatably connected at the lower portion **22***a* thereof to the pin **24**. The pick **22** is a thin narrow plate of soft magnetic material, and is rotatable about the pin **24**. The extension line of the centerline of the associated reed **33***b* is on the trajectory of the pick **22**. The pick **22** has an upper end portion **22***b*, which is wider than the lower end portion **22***a* so that a step **22***c* is formed at the boundary between the upper end portion **22***b* and the lower end portion **22***a*. The upper end portion **22***b* has a rounded end surface. On the other hand, the tip **33***c* of the reed **33***b* is tapered. While the plunger **26** is projecting from the bobbin **23**, the rounded end surface is brought into contact with the tapered tip **33***c*, and makes the reed **33***b* warped.

The spring **25** is connected at one end thereof to the upper portion of the pick **22** and at the other end thereof to the upper surface of the bottom yoke **25***a*. While the plunger **26** is resting in the bobbin **23**, the spring **25** is almost in its free length, and a negligible amount of elastic force is exerted on the pick **22**. The spring **25** increases the elastic force together with the distance between the pick **22** and the bottom yoke **25***a*, and urges the pick **22** outwardly. As described hereinbefore, when the current starts to flow through the coil **21***a*, the magnetic force makes the pick **22** inwardly inclined. The magnetic force is larger than the elastic force of the spring **25** in the initial stage where the pick **22** warps the reed **33***b*. When the step **22***c* exceeds the upper end of the bottom yoke **25***a*, the space between the pick **22** and the coil **21***a* is so wide that the magnetic force is equalized to the elastic force. The plunger **26** further projects upwardly, and the step **22***c* is spaced from the upper end **25***d*. Then, the elastic force becomes larger than the magnetic force, and the pick **22** escapes from the reed **33***b*. Then, the reed **33***b* vibrates for generating the tone. While the plunger **26** is being retracted into the bobbin **23**, the spring **25** keeps the pick **22** inclined outwardly. Thus, the spring **25** prevents the pick **22** from chattering.

The player's finger **20** behaves for plucking the associated reed **33***b* as follows. The controller **20**A is assumed to have already removed the magnetic field from the player's finger **20**. The pick **22** is outwardly inclined with respect to the centerline **26***a* of the plunger **26**, and the rounded upper end portion **22***b* is spaced from the tapered tip **33***c* as shown in FIG. **4**A.

When the current flows through the coil **21***a*, the pick **22** is inwardly inclined, and the plunger **26** starts to upwardly project against the elastic force of the string **25**. The plunger **26** is brought into contact with the tapered tip **33***c*, and pushes the reed **33***b* upwardly. Although the expanded spring **25** increases the elastic force exerted on the pick **22**, the magnetic force is still larger than the elastic force so that the pick **22** makes the reed **33***b* warped as shown in FIG. **4**B.

The plunger **26** further projects form the bobbin **23**, and the pick **22** becomes far from the coil **21***a*. When the magnetic force becomes smaller than the elastic force, the spring **25** pulls the pick **22** outwardly, and the pick **22** escapes from the reed **33***b*. Then, the reed **33***b* starts the vibrations, and generates the tone. The other player's fingers **20** behave along the above-described sequence so as to pluck the associated reeds **33***b*.

Turning to FIG. **3** of the drawings, the controller **20**A includes a central processing unit **11**, which is abbreviated as "CPU", read only memories **12**/**18**, which are abbreviated as "ROM"s, a random access memory **12**, which is abbreviated as "RAM", an MIDI (Musical Instrument Digital Interface) interface **14** and a driver circuit **17**. These system components **11**, **12**, **13**, **14**, **17** and **18** are connected to a bus system **15** so that the central processing unit **11** is communicable with the other system components through the bus system **15**. The driver circuit **17** is connected to the player's fingers

20 through a suitable cable, and selectively supplies the driving current to the player's fingers **20**.

Computer programs and data codes to be required for the execution of the computer programs are stored in the read only memory **12**, and the central processing system sequentially executes the instruction codes for achieving given tasks. The random access memory **13** serves as a working memory and a data storage for music data codes representative of pieces of music. The central processing unit **11** is further communicable with external musical instruments and a computer system through the MIDI interface **14**. A set of MIDI music data code representative of a piece of music may be supplied from an external data source to the MIDI interface **14**, and the central processing unit **11** stores the set of MIDI music data codes into the random access memory **13** for a performance on the daisy reed wheel **32**.

The read only memory **18** offers a data storage facility for parameters, and the central processing unit **11** accesses the parameters during the execution of the given computer program.

Assuming now that a user instructs the automatic player **5** to perform a piece of music represented by a set of MIDI music data codes on the daisy reed wheel **32**. The set of MIDI music data codes has been already stored in the random access memory **13**. As well known to skilled person, event codes and duration codes form essential parts of the set of MIDI music data codes. The tones to be generated and the loudness of the tones are represented by the event codes, and each duration data code is indicative of a time interval between the event or events, i.e., note-on event/note-off event and the next event.

The central processing unit **11** executes a computer program so as to determine the reeds **33***b* to be driven for vibrations, the timing to supply a driving signal to the associated player's fingers **20** and the magnitude of the driving signal as follows. While the central processing unit **11** sequentially fetches the MIDI music data codes from the random access memory **13**, an event code just fetched by the central processing unit **11** is assumed to represent the note-on event for generating a tone. The central processing unit **11** specifies one of the reeds **33***b*. The central processing unit **11** accesses the parameters and data codes stored in the read only memories **12**/**18**, and determines the magnitude of the driving signal for generating the tone at the given loudness.

When the time at which the tone is to be generated comes, the central processing unit **11** supplies data codes representative of the position assigned to the player's finger to be energized and the magnitude of the driving signal to be supplied to the driver circuit **17**. Then, the driver circuit **17** sets the driving signal to the magnitude, and supplies the driving signal to the solenoid-operated actuator **21** incorporated in the player's finger **20**. The solenoid-operated actuator **21** maintains the pick **22** at the rest position P3. When the driving signal reaches the coil **21***a*, the current creates the magnetic field across the bobbin **23**. The magnetic force is exerted on the pick **22** as well as the plunger **26**. The pick **22** is inclined toward the tip **33***c* of the associated reed **33***b* against the elastic force of the spring **25**, and the plunger **26** upwardly projects. The pick **22** upwardly pushes the tip **33***c* of the reed **33***b* so that the reed **33***b* is warped.

Though not shown in FIG. **3**, the driver circuit **17** includes a pulse width modulator. The pulse width modulator incorporated in the driver circuit **17** controls the loudness of the tones to be produced through the vibrations of the reeds **33***b*. The central processing unit **11** is assumed to instruct the driver circuit **17** to supply the driving signal for generating a loud tone. The pulse width modulator increases the pulse width of the driving signal, and supplies it to the solenoid-operated actuator associated with the reed **33***b* to be plucked. When the driving signal reaches the coil **21***a*, a large amount of current flows, and creates a strong magnetic field. The pick **22** is strongly attracted to the inner portion of the additional yoke **25***d*, and the plunger upwardly projects from the bobbin **23** powerfully. The magnetic force is so large that the spring can not outwardly incline the pick **22** as usual. Thus, the driving signal with the wide pulse width results in the strong attractive force exerted on the pick **22** as well as the speed-up of the plunger **26**. For this reason, the pick **22** makes the reed **33***b* widely warped. However, the elastic force exceeds the magnetic force later than usual. Then, the pick **22** escapes from the tapered tip **33***c*, and permits the reed **33***b* to vibrate. The escape is later than the usual escape is. This means that the reed **33***b* is widely warped, and the amplitude of the vibrations is wider than the amplitude of the usual vibrations. This results in the loud tone.

When the elastic force exceeds the magnetic force, the spring **25** pulls the pick **22** outwardly, and the pick **22** escapes from the reed **33***b*. The pick **22** plucks the reed **33***b* so that the reed **33***b* naturally vibrates. The clear tone is generated through the naturally vibrating reed **33***b*. Upon escape, the pick **22** is changed to position **P1**.

The driving circuit **17** removes the driving signal from the solenoid-operated actuator **21**. Then, the plunger **26** is retracted due to the self-weight and the elastic force of the spring **25**, and the spring **25** outwardly inclines the pick **22** as indicated by **P2**. The cushion sheet **23***a* receives the plunger **26**. While the plunger **26** is sinking together with the pick **22**, the pick **22** never interferes with the vibrating reed **33***b*, because the spring **25** keeps the pick **22** outwardly inclined. In order to prevent the vibrating reed **33***b* from interference, the spring **25** slightly inclines the pick **22** so that the additional space to be required is negligible. Thus, the music box implementing the first embodiment is made compact by virtue of the radial arrangement of the reeds **33***b* and the picks **22** outwardly inclined.

As will be understood from the foregoing description, the daisy reed wheel **32** occupies the central zone of the inner space defined in the housing **1**, and the reeds **33***b* radially extend from the boss portion **33***a*. This feature is desirable, because the automatic player **5** occupies the wide peripheral zone around the tips **33***c* of the reeds **33***b*. Thus, the tone generator **3** and automatic player **5** do not waste the inner space. This results in the compact music box.

Moreover, the tips **33***c* are widely spaced so that the wide local spaces are assigned to the player's fingers **20**. The player's fingers **20** require the actuators **21** for plucking the reeds **33***b*. The designer can install large-sized actuators in the wide local spaces so that the player's fingers **20** perform a piece of music at a high tempo. The designer can further install the strong picks **22** on the large-sized plungers **26**. Thus, the music box is durable.

Yet another advantage is resulted from the pick's action. The picks **22** upwardly push the tips **33***c* of the associated reeds **33***b*, and, thereafter, escape from the tips **33***c* outwardly. The picks **22** pluck the associated reeds **33***b* as if a human player plucks strings or reeds with his or her fingers. Thus, the picks **20** naturally give rise to vibrations of the reeds **33***b*. This results in clear tones.

Still another advantage is also resulted from the pick's action after the plucking. The springs **25** elastically pull the picks **22**, and the picks **22** are outwardly inclined. The outwardly inclined picks **22** return to the initial positions without interference with the vibrating reeds **33***b*. Only a small amount of space is required for the outwardly inclined picks **22**. Thus, the pick's action is conducive to the compactness of the music box.

The solenoid-operated actuators **21** are independently controlled by the controller **20**A. This means that the controller **20**A can concurrently energize more than one solenoid-operated actuator **21**. Thus, the automatic player **5** can play a piece of music along the melody accompanied with chords.

The controller **20**A sequentially energizes the solenoid-operated actuators **21** on the basis of the music data, and the user arbitrarily changes the music data. Thus, the music box is responsive to any user's request for performing tunes.

Several Models of Music Box

Various modifications of the music box implementing the first embodiment are hereinafter described in detail. FIG. **6**A shows the external appearance of the music box described hereinbefore. The first modification has a casing **1**A, and light-emitting diodes **46** are provided along the periphery of the upper surface of the casing as shown in FIG. **6**B. The light-emitting diodes **46** are respectively associated with the reeds **33***b*, and are connected in parallel to the controller **20**A. The controller **20**A energizes the light-emitting diodes **46** concurrently with the solenoid-operated actuators **21** for the reeds **33***b* to be plucked. Thus, the tones are harmonized with the light.

The second modification has a casing **1**B, on which a megaphone **47** is provided as shown in FIG. **6**C. The megaphone **47** makes the tones loud. The third modification has a casing **1**C provided with the light-emitting diodes like the casing **1**A of the first modification. A semi-transparent cupola **48** is attached to the casing **1**C as shown in FIG. **6**D. The semi-transparent cupola **48** disperses the light, and gives fantastic impression. An illumination system may be provided inside of the semi-transparent cupola **48** independently of the solenoid-operated actuators **21**.

Multiple Music Box

The tone generator and automatic player may be multiplexed. FIG. **7**A shows an example of the multiple music box according to the present invention. The multiple music box comprises plural performing units **41**, a cylindrical post **42** and a resonator box **43**. Each of the performing units **41** includes the daisy reed wheel **3** and the automatic player **5**, which are similar to those of the music box described hereinbefore. A tone hole **43***a* is formed in the upper plate of the resonator box **43**, and the resonator **43***b* is connected through the tone hole **43***a* to the column-shaped space **42***a* defined in the cylindrical post **42**. Plural trays **42***b* project from the outer surface of the cylindrical post **42**, and the performing units **41** are respectively mounted on the trays **42***b*.

Different registers are respectively assigned to the performing units **41** so that the multiple music box produces a piece of music in plural parts. The automatic players **5** of the plural performing units **41** are connected to the controller **20**A, and the driver circuit **17** selectively supplies the driving signal to the solenoid-operated actuators **21**. When the solenoid-operated actuators **21** are energized, the player's fingers **20** pluck the associated reeds with the picks **22**. The tones and vibrations are propagated though the cylindrical post **42** to the resonator **43***b* so that the loud tones are radiated from the resonator box **43**.

FIG. **7**B shows another example of the multiple music box. The multiple music box comprises plural performing units **141**, the resonator box **43** and a combined structure of cylindrical post and bell **44**/**45**. The combined structure of cylindrical post and bell **44**/**45** is upright on the resonator box **43**, and brims **44***a* are formed together with the trays **42***b*. Each of the performing units **141** has the daisy reed wheel **32** and the automatic player **5**. The daisy reed wheels **32** are detachably connected to the brims **44***a*, and the resonator **43***b* is connected through the bell **45** to the air. The multiple music box produces loud tones, and the daisy reed wheels **32** are easily replaced with another daisy reed wheels.

Unitized Structure

A reed and a player's finger may form a tone generating unit. In this instance, plural tone generating units may be arranged on a virtual circle. FIG. **8**A shows an example of the tone generating unit **100**. The tone generating unit **100** largely comprises a holder **110**, a player's finger **120** and a reed **133**. The player's finger **120** is similar in structure to the player's finger **20** so that no further description is hereinafter incorporated for the sake of simplicity.

The holder **110** is a generally rectangular parallelepiped configuration. A pair of flanges **111** is formed in one end portion, and a through-hole is formed in the other end portion. Bolt holes **11***a* are formed in the pair of flanges **111**, and the player's finger **120** is received in the through-hole. The plunger is projectable and retractable in a direction indicated by arrow AR2. The one end portion is thicker than the other end portion so that a step **110***a* takes place at the boundary therebetween. The reed **133** is fixed to the one end portion by means of bolts. The boss portion **132** of the reed **133** is held in contact with the one end portion. However, the remaining portion of the reed is overhung like a cantilever. The tip **133***a* of the reed **133** is over the pick without physical contact as shown. When the solenoid-operated actuator is energized with the driving signal, the pick is inclined toward the tip **133***a*, and the plunger upwardly projects from the bobbin. The pick upwardly pushes the reed **133**, and warps it. The pick escapes from the tip **133***a*, and permits the reed **133** to vibrate. The magnetic field is removed from the solenoid-operated actuator, and the plunger is retracted into the bobbin together with the pick. Thus, the player's finger behaves as similar to the player's finger **20**.

The tone generating unit or units **100** are attached to any sort of frame. FIG. **8**B shows the tone generating units **100** fixed to a disk **100***a*. The tone generating units **100** are arranged on a virtual circle **100***b*, and are fixed to the disk **100***a* by means of the screws. In this instance, the tone generating units **100** occupy an inner space between the disk **100***a* and an outer space assigned to the automatic player. Although the through-holes of the holders **110** are directed in the tangential directions of the virtual circle **100***b* on the disk **100***a*, the through-holes may be arbitrarily directed on another disk **100***a*.

The tone generating units **100** occupy a relatively narrow space, and a compact music box or musical instrument is realized with an array of tone generating units **100**.

Stringed Instrument

The reeds do not set any limit on the musical instrument according to the present invention. Any sort of vibratory member is available for the musical instrument. Strings are one of the sorts of vibratory members.

FIGS. **9**A and **9**B shows an example of the stringed instrument. The stringed instrument may serve as a part of a music box. The stringed instrument largely comprises a housing **1**A, a tone generator **3**A implemented by strings **233** and an automatic player **5**A.

The housing **1**A includes the bottom disk **10** and a cylindrical wall **38**. The cylindrical wall **38** and bottom disk **10** are assembled into the housing, and define a space over the upper surface of the bottom disk **10**. The tone generator **3**A and automatic player **5**A are accommodated in the space.

The tone generator **3**A includes the pedestal **31**, an inner frame **34**, an outer frame **37** and strings **34** stretched between the inner frame **34** and the outer frame **37**. The pedestal **31** is upright on the upper surface **10***a* of the bottom disk **10**, and is fixed to the bottom disk **10**. The inner frame **34** is made of metal or alloy. The inner frame **34** is reinforced with beams **35**, and the distance between the center of the pedestal **31** and the periphery of the inner frame **34** is varied together with the angle. The frame **34** is horizontally disposed on the upper surface of the pedestal **31**, and is fixed thereto by means of a bolt **36**. The outer frame **37** is circular, and is fixed to the cylindrical wall **38**. The distance between the inner frame **34** and the outer frame **37** is varied together with the angle. The strings **233** are stretched between the inner frame **34** and the outer frame **37**, and are different in thickness and length for generating tones different in pitch from one another. In this instance, twenty-four strings **233** are incorporated in the tone generator **3**A.

Since the strings **233** radially extend between the inner frame **34** and the outer frame **37** so that the strings **233** are spaced from the adjacent strings **233** at the outer ends wider than at the inner ends. Thus, the radial arrangement of the strings **233** offers wide local spaces to the automatic player **5**A along the outer frame **37**.

The automatic player **5**A includes player's fingers **220** and a controller (not shown). The player's finger **220** is similar in structure to the player's finger **20**, and a solenoid-operated actuator **21**, a pick **22** and a spring **25** form parts of each player's finger **220**. The player's fingers **220** are respectively associated with the strings **233**, and each player's finger **220** is disposed on one side of the associated string **233**.

When a user requests the automatic player **5**A to perform a piece of music, the controller (not shown) selectively supplies the driving signal to the solenoid-operated actuators **21** associated with the strings **233** to be plucked. The picks **22** are inclined toward the associated strings **233**, and the plungers upwardly project from the bobbins. The picks **22** push the strings **233** upwardly Then, the picks **22** escape from the associated strings **233**, and permit the strings **233** to vibrate. The picks **22** are inclined toward the opposite sides of the associated strings **233**. The controller removes the magnetic field from the solenoid-operated actuators **220**. Then, the plungers are retracted into the bobbins, and the inclined picks **22** return to the rest positions without any interference with the vibrating reeds **33***b*.

It is preferable to pluck the strings **233** at which each string **233** is divided at 1:7. In this instance, the player's fingers **220** are located around the optimum positions. However, the player's fingers are just located at the respective optimum positions.

Second Embodiment

Prototype

FIGS. **10**A and **10**B show another musical instrument embodying the present invention. The musical instrument shown in FIGS. **10**A and **10**B is categorized in a music box. The musical instrument largely comprises a housing **1**B, a tone generator **3**B and an automatic player **5**B. The housing **1**B and tone generator **3**B are similar in structure to the housing **1** and tone generator **3**. For this reason, the component parts of the housing/tone generator **1**/**3** are labeled with the references designating the corresponding component parts of the housing/tone generator **1**/**3** without detailed description.

The automatic player **5**B also comprises player's fingers **20**B and a controller **20**Aa. The system components of the controller **20**Aa are similar to those of the controller **20**A (see FIG. **12**). In the controller **20**Aa, the driver circuit **17***a* includes a pulse width modulator **17***b*. The pulse width modulator **17***b* varies the pulse width of the driving signal depending upon the loudness of a tone to be generated as will be described hereinlater.

The players fingers **20**B are arranged in the peripheral zone of the inner space defined in the housing **1**B, and are in the close proximity of the tips **33***c* of the reeds **33***b*. The player's fingers **20**B are similar in structure to one another. As will be better seen in FIGS. **11**A and **11**B, the player's finger **20**B includes the solenoid-operated actuator **21**, a pick **22**B and the spring **25**.

The pick **22**B is rotatably connected to the pin **24**, which in turn is supported by the plunger **26**. The pick **22**B has a relatively narrow lower portion **22***a* and a relatively wide upper portion **22***b* so that the step **22***c* takes place at the boundary between the upper end portion **22***b* and the lower end portion **22***a*. The pick **22**B has an end surface **22***f* partially flat and partially rounded. The flat area is brought into contact with the tapered tip **33***c* during the upward motion of the plunger **26**, and pushes the tapered tip **33***c* so as to warp the reed **33***b*. When the elastic force exceeds the magnetic force, the spring **25** inclines the pick **22**B outwardly. Then, the rounded area slides on the tapered tip **33***c*, and the pick **22**B escapes from the tapered tip **33***c*. Thus, the rounded area makes the escape smooth, and the pick **22**B is never caught on the tapered tip **33***c*.

The pulse width modulator **17***b* incorporated in the driver circuit **17***a* controls the loudness of the tones to be produced through the vibrations of the reeds **33***b*. The central processing unit **11** is assumed to instruct the driver circuit **17***a* to supply the driving signal for generating a loud tone. The pulse width modulator **17***b* increases the pulse width of the driving signal, and supplies it to the solenoid-operated actuator associated with the reed **33***b* to be plucked. When the driving signal reaches the coil **21***a*, a large amount of current flows, and creates a strong magnetic field. The pick **22**B is strongly attracted to the inner portion of the bottom yoke **25***a*, and the plunger upwardly projects from the bobbin **23** powerfully. The magnetic force is so large that the spring can not outwardly incline the pick **22** as usual. Thus, the driving signal with the wide pulse width results in the strong attractive force exerted on the pick **22** as well as the speed-up of the plunger **26**. For this reason, the pick **22**B makes the reed **33***b* widely warped. However, the elastic force exceeds the magnetic force later than usual. Then, the pick **22** escapes from the tapered tip **33***c*, and permits the reed **33***b* to vibrate. The escape is later than the usual escape is. This means that the reed **33***b* is widely warped, and the amplitude of the vibrations is wider than the amplitude of the usual vibrations. This results in the loud tone.

Assuming now that a user requests the automatic player **5**B to perform a piece of music, the central processing unit **11** sequentially fetches the music data codes from the random access memory **13**. One of the music data codes is assumed to represent the note-on event for generating a tone. When the time at which the tone is to be generated comes, the central processing unit **11** instructs the driving circuit **17***a* to supply the driving signal to the associated solenoid-operated actuator **21**. The driving circuit **17***a* determines the optimum pulse width, and the pulse width modulator **17***b* adjusts the driving signal to the optimum pulse width. The driving signal is supplied to the coil **21***a*, and creates the magnetic field. The pick **22**B was resting at position **P3** before reaching the driving current. When the magnetic field is created, the pick **22**B is inwardly inclined, and the plunger **26** starts to lift the pick **22**B.

The pick **22**B is brought into face-to-face contact with the tapered tip **33***c* at the flat area of the upper surface **22***f*. The upper surface **22***f* pushes the tapered tip **33***c*, and warps the reed **33***b*. While the plunger **26** is upwardly projecting, the magnetic force is weakened, and the elastic force of the spring **25** is increased. When the elastic force exceeds the magnetic force, the spring **25** pulls the pick **22**B, and outwardly inclines the pick **22**B as indicated by **P1**. While the spring **25** is inclining the pick **22**B, the rounded area of the upper surface **22***f* smoothly slides on the tapered tip **33***c* until the escape from the tapered tip **33***c*.

The driver circuit **17***a* recovers the driving signal to the inactive level. The magnetic field is removed from the solenoid-operated actuator **21**, and the magnetic force is exerted on the pick **22**B. For this reason, the spring **25** further inclines the pick **22**B outwardly as indicated by **P2**. The plunger **26** is retracted into the bobbin **23**, and the pick **22**B returns to the rest position as indicated by **P3**.

As will be appreciated from the foregoing description, the musical instrument implementing the second embodiment achieves all the advantages of the first embodiment. Moreover, the spring **25** inclines the pick **22**B outwardly so that the pick **22**B returns to the rest position without interference with the vibrating reed **33***b*. The automatic player **5**B merely requires an additional space, which permits the outwardly inclined picks **22**B to return to the rest positions thereof. Any other space is not required for the player's fingers **20**B. The additional space is negligible in the inner space of the housing **1**B so that the musical instrument is compact.

Another attractive point of the musical instrument according to the present invention is forcibly to incline the pick **22**B after the plucking. The outwardly inclined pick **22**B never interferes with the vibrating reeds **33***b*. This results in clear tones. Moreover, the springs **25** continuously exert the elastic force on the pick **22**B until returning to the rest position. Thus, the springs **25** prevent the picks **22**B from chattering.

Yet another attractive point of the music instrument according to the present invention is the upper surfaces **22***f* of the picks **22**B which have the respective flat areas and respective rounded areas. While the picks **22**B is warping the tips **33***c* of the associated reeds **33***b*, the flat areas are held in contact with the flat surfaces of the associated tapered tips **33***c* so that the force is effectively transferred from the picks **22**B to the reeds **33***b* without slippage. When the springs **25** pull the picks **22**B outwardly, the rounded area slide on the flat surfaces of the tapered tips **33***c* so that the picks **22**B smoothly escape from the reeds **33***b*.

Other Player's Fingers

The musical instrument implementing the second embodiment are modified as follows. First, the player's fingers **20**B are replaced with player's fingers **20**C shown in FIG. **14**. The player's finger **20**C includes a solenoid-operated actuator **21**C, the spring **25**, a pick **162** and a guide block **163**. The solenoid-operated actuator **21**C is similar to the solenoid-operated actuator **21** except a plunger **161**. For this reason, the other component parts are labeled with the references designating the corresponding component parts of the solenoid-operated actuator **21** without detailed description.

The plunger **161** is slidably received in the bobbin **23**, and a slit **161***a* is formed in the upper end portion of the plunger **161**. The slit **161***a* is opened at the outer end, and is closed at the inner end. In other words, a pair of side surfaces and an inner end surface **161***b* define the slit **161***a*. The pin **24** is provided in the upper portion of the plunger **162** across the slit **161***a*, and the pick **162** is rotatably supported at the lower end of the stem portion **162***a* thereof by the pin **24**. The pick **162** is rotatable on a trajectory, which is aligned with the centerline of the associated reed **33***b*. However, the inner end surface **161***b* sets a limit to the rotation of the pick **162**, and the inner end surface **161***b* causes the pick **162** to be brought into contact with the tapered tip **33***c* of the associated reed **33***b*. The pick **162** is made of soft magnetic material.

The pick **162** is like a plate, and has a head portion **162***b* at the upper end of the stem portion **162***a*. The head portion **162***b* projects inwardly and outwardly from the stem portion **162***a*, and the spring **25** is connected between the head portion **162***b* and the upper surface of the bottom yoke **25***a*. The head portion **162***b* has a rounded upper surface. The rounded upper surface is steep in the inward direction, and is gentle in the outward direction. The part of the head portion **162***b* inwardly projecting from the stem portion **162***a* is hereinafter referred to as "inner sub-portion **162***b***1**", the top of the head portion is labeled with **162***b***2**, and the part of the head portion **162***b* outwardly projecting from the stem portion **162***a* is referred to as "outer sub-portion **162***b***3**". The tip of the inner sub-portion **162***b***1** is rounded.

The guide block **163** is fixed to the bottom yoke **25***a*. The guide block **163** rises from the upper surface of the bottom yoke **25***a*, and inwardly projects. The inner end portion of the guide block **163** is spaced from the associated reed **33***b* so that the vibrating reed **33***b* does not beat the inner end portion. The guide block **163** has three guide surfaces **163***a*, **163***b* and **163***c* over the pick **162**. As will be described hereinafter in detail, the head portion **162***b* is firstly brought into contact with the guide surface **163***a*, thereafter, slides on the guide surfaces **163***a*, **163***b* during the escape, and the guide surface **163***c* leads the head portion **162***b* to the rest position. Thus, the guide block **163** defines the behavior of the pick **162** in the reciprocal motion.

The reference **162(P0)** is indicative of the pick at the rest position. Assuming now that the controller energizes the solenoid-operated actuator **21**C, the magnetic field is created, and the plunger **161** starts to project from the bobbin **23**. The pick **162** is inwardly attracted in the magnetic field. For this reason, although the elastic force of the spring **25** is increased together with the upward motion of the plunger **161**, the stem portion **162***a* is pressed to the inner end surface **161***b*.

The inner sub-portion **162***b***1** is brought into contact with the tapered tip **33***c* as indicated by **162(P1)**. The plunger **161** further projects upwardly, and the head portion **162***b* warps the reed **33***b*. The inner sub-portion **162***b***1** keeps the face-to-face contact with the tapered tip **33***c* so that the force is effectively exerted on the reed **33***b*. When the pick **162** reaches the position indicated by **162(P2)**, the elastic force of the spring **25** becomes larger than the magnetic force, and the pick **162** outwardly inclined. The inner sub-portion **162***b***1** slides on the tapered tip **33***c*, and the pick **162** escapes from the reed **33***b*. Since the tip of the inner sub-portion **162***b***1** is rounded, the pick **162** smoothly escapes from the reed **33***b*.

The plunger **161** further projects, and the inner sub-portion **162*b*1** is brought into contact with the guide surface **163*a*** as indicated by **162**(P**3**). The guide surface **163*a*** makes the head portion **162*b*** further spaced from the reed **33*b***, and the pick **162** is further inclined outwardly. The elastic force of the spring **25** is increased together with the stroke of the plunger **161**, and the magnetic force is weakened. The head portion **162*b*** slides on the guide surface **163*b***, and reaches the guide surface **163*c*** as indicated by **162**(P**4**).

The magnetic field is removed from the solenoid-operated actuator **21**C, and the plunger **161** is retracted into the bobbin **23**. The elastic force is still exerted on the pick **162**, and the outer sub-portion **162*b*3** downwardly slides on the guide surface **163*c***. The plunger **161** is softly received on the cushion sheet **23*a***, and the pick **162** reaches the rest position **162**(P**1**).

As will be understood, the guide block **163** defines the trajectory of the pick **162**, and prevents the pick **162** from damage due to excess force. This results in that the pick **162** is durable.

FIGS. **15**A to **15**F shows another modification **20**D of the player's finger. The player's finger **20**D includes a solenoid-operated actuator **21**D, a spring **176** and a guide block **174** and a pick **175**. The solenoid-operated actuator **21**D includes a yoke **171**, a coil **172** and a plunger **173**. The yoke **171** has a cylindrical space, and the plunger **173** is slidably received in the cylindrical space. The coil **172** is wound around the plunger **173**. The upper portion of the plunger **173** is partially cut off (see FIG. **15**B), and the pick **175** is rotatably connected to the plunger **171** by means of a pin.

The yoke **171** has a flat upper surface, and any projection is not formed in the inner portion thereof. For this reason, the magnetic force is not exerted on the pick **175** so as to make the pick **175** inclined inwardly.

The pick **175** has a plate portion **175*a*** and a head portion **175*b***. The plate portion **175*a*** is rotatably connected to the pin. The head portion **175*b*** has an inner rounded end surface **175*c***. The spring **176** is connected at one end thereof to the head portion **175*b***, and is anchored to the upper surface of the yoke **171**. The anchored portion is sidewardly offset from the trajectory of the pick **175** so that the pick **175** is sidewardly outwardly urged. In other words, the pick **175** is urged outwardly as similar to the pick **162**, and is further urged in the direction indicated by F**4** (see FIG. **15**F) A guide pin **179** passes through the head portion **175*b***, and sideward projects from both side surfaces of the head portion **175*b***.

The guide block **174** is fixed to the yoke **171**, and is shaped like a channel, When the guide block **174** is fixed to the yoke **171**, a hollow space is defined. The reed **33*b*** projects into the hollow space as shown in FIG. **15**A. The guide block **174** has a pair of side walls **174*a***/**174*b***, and the side wall **174*a*** is in parallel to the other side wall **174*b***. Guide grooves **174*a*1** and **174*b*1** are respectively formed in the side walls **174*a***/**174*b***, and the pin **179** is loosely received at both end portions thereof to the guide grooves **174*a*1**/**174*b*1**. The guide groove **174*a*1** has an upward path **174*a*1**A and a downward path **174*a*1**B. The lowermost end of the upward path **174*a*1**A is the lower dead point **174*a*01** of the guide groove **174*a*1**, and the uppermost end of the downward path **174*a*1**B is the upper dead point **174*a*02** of the guide groove **174*a*1**. The guide groove **174*a*1** is deepest at the lower dead point **174*a*01** and upper dead point **174*a*02** (see FIG. **15**D). The upward path **174*a*1**A becomes shallower along the curved portion **174*a*21**, and the curved portion **174*a*21** is connected to the downward path **174*a*1**B. However, the curved portion **174*a*21** is shallower than the downward path **174*a*1**B at the boundary therebetween so that a step **174*a*11** takes place. Similarly, the downward path **174*a*1**B becomes shallower along the curved portion **174*a*22**, and is connected to the upward path **174*a*1**A. The curved portion **174*a*22** is also shallower than the upward path **174*a*1**A so that a step **174*a*12** takes place at the boundary therebetween. The other guide groove **174*b*1** also has an upward path and a downward path, and the upward path and downward path are arranged in parallel to the upward path **174*a*1**A and downward path **174*a*1**B, respectively. However, any step is not formed between the upward path and the downward path. The spring **176** always urges the pick **175** toward the side wall **174*a*** so that the pin **179** slides on the bottom surfaces of the upward/downward paths **174*a*1**A/**174*a*1**B.

The pin **179** is moved along the guide grooves **174*a***/**174*b***. While the plunger **173** is projecting from the yoke **171**, the pick **175** is moved upwardly together with the plunger **173**, and the upward paths **174*a*1**A guide the pin **179**. The pin **179** passes through the curved portion **174*a*21**, and enters the downward path **174*a*1**B. Although the pin **179** passes through the boundary between the downward path **174*a*1**B and the curved portion **174*a*21** in the downward motion, the pin **179** does not enter the curved portion **174*a*21**, because the step **174*a*11** does not permit the pin **179** to enter the curved portion **174*a*21**. Similarly, the step **174*a*12** does not permit the pin **179** to enter the curved portion **174*a*22** in the upward motion. Thus, the head **175*a*** is traced along a trajectory TR (see FIG. **15**F), and plucks the reed **33*b*** as will be described hereinafter in detail.

While any current does not flow through the coil **172**, the pick **175** is staying at the rest position **175**(P**0**). Assuming now that the controller (not shown) energizes the solenoid-operated actuator **21**D, the magnetic field is created, and gives rise to the upward motion of the plunger **173**. The plunger **173** upwardly lifts the pick **175**, and the pin **179** slides on the bottom surface from the lower dead point **174*a*01** to the boundary between the straight portion and the curved portion **174*a*21**. Since the depth is constant, the head **175*b*** is straightly moved toward the tip of the associated reed **33*b***. When the head **175*b*** is brought into contact with the tip of the reed **33*b***, the pin **179** is still on the way to the boundary between the straight portion and the curved portion **174*a*21**. The head **175*b*** is further moved upwardly, and warps the reed **33*b***.

The pin **179** enters the curved portion **174*a*21**. Then, the head **175*b*** starts to laterally slide on the tapered tip of the reed **33*b***. The elastic force of the spring **176** is increased together with the plunger stroke, and makes the pick **175** outwardly inclined. The elastic force becomes large so that the pick **175** escapes from the reed **33*b***. The reed **33*b*** freely vibrates for generating the tone. The plunger **173** further projects, and the pin **179** enters the downward path **174*a*1**B over the step **174*a*11**. The head **175*b*** becomes offset from the vibrating reed **33*b***.

The controller (not shown) removes the magnetic field from the solenoid-operated actuator **21**D so that the plunger **173** and, accordingly, pick **175** start to sink downwardly. The pin **179** slides on the bottom surface of the downward path **174*a*1**B toward the boundary between the straight portion and the curved portion **174*a*22**. Since the depth is constant, the pick **175** passes beside the vibrating reed **33*b***, and does not interfere with the vibrating reed **33*b***. When the pin **179** reaches the boundary, the head **175*b*** is below the vibrating reed **33*b***. Then, the pin **179** enters the upward path over the step **174*a*12**. Although the head **175*b*** returns to the space beneath the reed **33*b***, the head **175*b*** does not interfere with the vibrating reed **33*b***. Finally, the pin **179** slides on the bottom surface of the straight portion to the lower dead point **174*a*01**, and reaches the rest position.

Thus, the pin **179** and guide block **174** shunt the head portion **175*b*** from the upward pass to the downward path after the plucking, and make the head portion **175*b*** pass beside the vibrating reed **33*b***. The pick **175** never interfere with the vibrating reed **33*b*** so that the musical instrument generates clear tones.

FIGS. **16** and **17** show an automatic player, in which another modification of the player's fingers. The player's fingers **20**E form parts of the automatic player together with a controller **20**Ab, and the automatic player in turn forms a musical instrument together with an array **48** of reeds. The musical instrument is categorized in the music box. The array **48** includes a base plate **47** and reeds **48*a***, and the reeds **48*a*** project from the base plate **47** in parallel to one another. Thus, the comb-like reed array is used in the musical instrument. The player's fingers **20**E are associated with the reeds **48*a***, respectively, and are disposed in the proximity of the tips of the associated reeds **48*a***.

The controller **20**Ab causes the player's fingers **20**E to selectively pluck reeds **48**. The system configuration of the controller **20**Ab is similar to that of the controller **20**Aa, and the system components are labeled with references designating corresponding system components of the controller **20**Aa without detailed description.

The player's fingers **20**E include respective solenoid-operated flat actuators FLAT**1**, respective blades **45** and respective rotary picks **46**. Plural permanent magnet plates **41** are alternated with yokes **42** so as to form a magnetic block, which is shared among the solenoid-operated flat actuators FLAT**1**. The magnetic block is fixed to a base **55** in such a manner that the permanent magnet plates **41** are elongated in directions in parallel to the centerlines of the associated reeds **48*a***. The permanent magnet plates **41** are made of magnetic material containing a rare earth element such as, for example the magnetic material in neodymium series.

The yokes **42** have a same shape. Each yoke **42** has a thin portion **42*a*** and a thick portion **42*b***. The thin portion **42*a*** is sandwiched between two permanent magnetic plates **41**, and the thick portion **42*b*** projects over the permanent magnetic plates **41**. Since the thick portion **42*b*** is thinner than the permanent magnetic plate **41**, the adjacent thick portion **42*b*** is spaced from the adjacent thick portions **42*b***, and gaps take place between the thick portions **42*b***. The yokes **42** offer magnetic paths to the magnetic field created by the permanent magnet plates **41**, and the magnetic field are created across the gaps.

Each of the solenoid-operated flat actuators FLAT**1** further includes a swingable arm **43** and a flat coil **44**. The swingable arm **43** has both side surfaces substantially in parallel to a virtual plane on which the centerline of the associated reed **48*a*** extends. The flat coil **44** is fixed to one of the side surfaces of the swingable arm **43**, and a pin **49** is fixed to the swingable arm **43**. The pin **49** sidewardly projects from the side surfaces of the swingable arm **43**, and is rotatably supported by a frame (not shown). Thus, the swingable arm **43** and, accordingly, the flat coil **44** are rotatably supported by the frame. Although the gaps are respectively assigned to the swingable arms **43**, only one swingable arm **43** is illustrated in FIG. **17**. While any current does not flow through the flat coil **44**, the flat coil **44** is resting in the magnetic field created in the gap. When the current flows through the flat coil **44**, the magnetic force is exerted on the flat coil **44**, and causes the flat coil **44** and, accordingly, the arm **43** to move in the direction determined on the basis of the Fleming's left-hand rule. Thus, the current flowing through the flat coil **44** gives rise to the rotation of the swingable arm **43** about the centerline **49*a*** of the pin **49** in the counter clockwise direction in FIG. **17**. When the controller **20**Ab stops the current, the self-weight of the swingable arm/flat coil **43**/**44** return to the rest position in the gap. The trajectory of the swingable arm **43** is substantially coplanar with the vibrating reed **48*a***.

The blade **45** is made of metal or alloy, and is fixed to the leading end of the swingable arm **43**. The blade **45** has a leading end portion slightly inclined to the associated rotary pick **46**. For this reason, the blade **45** gives rise to rotation of the rotary pick **46** without slippage. Thus, the force is surely transferred from the blade **45** to the rotary pick **46**. While the swingable arm **43** is resting in the gap, the blade **45** upwardly projects from the swingable arm **43** (see FIG. **18**A). The blade **45** is rotated together with the swingable arm **43** when the current flows through the flat coil **44**.

The rotary picks **46** are made of metal or alloy, and are respectively associated with the reeds **48*a***. Spacers **50** are alternated with the rotary picks **46** so as to make the rotary picks **46** confronted to the associated reeds **48*a*** (see FIG. **18**B). The rotary picks **46** are arrayed as similar to the reeds **48*a***. Each of the rotary picks **46** has plural claws **46*a*** and a disk **46*b***. In this instance, claws **46*a*** radially project from the disk **46*b*** at regular intervals. In other words, each claw **46*a*** is spaced from the adjacent claws **46*a*** at 90 degrees. The disk **46*b*** is rotatably supported by the frame. Although the disk **46*b*** is spaced from the tip of the associated reed **48*a***, the claws **46*a*** reach the reed **48*a***, and pluck the reed **48*a*** for vibrations. A ratchet **53** is provided for each of the rotary pick **46** so that the rotary pick **46** is rotatable about a centerline **46*c*** only in the counter clockwise direction in FIG. **17**.

While the swingable arm **43** is resting in the gap, the tip of the blade **45** is located in the close proximity of one of the claws **46*a***. When the swingable arm **43** is rotated, the tip of the blade **45** pushes the claw **46*b*** so that the rotary pick **46** is driven for rotation, and another claw **46*b*** pushes the tip of the reed **48*a*** downwardly. The claw **46*b*** is further rotated, and is spaced from the tip of the reed **48*a***. Thus, the rotary pick **46** plucks the reed **48*a*** for vibrations.

The claw **46*a*** has a rounded front surface **46*a*2** and a flat back surface **46*a*1** (see FIG. **18**A). The blade **45** pushes the flat back surface **46*a*1** so that the force is certainly exerted on the claw **46*a***. On the other hand, the rounded front surface **46*a*2** is brought into contact with the tip of the reed **48*a***, and makes the reed **48*a*** warped. The tip of the reed **48*a*** smoothly slides on the rounded front surface **46*a*2** so that the claw **46*a*** is never caught on the reed **48*a***.

Assuming now that a user requests the automatic player to perform a piece of music, the central processing unit **11** sequentially accesses music data codes stored in the memory **13**, and instructs the driver circuit **17** to selectively energize the solenoid-operated flat actuators FLAT**1**. While the central processing unit **11** is sequentially processing the music data, the central processing unit **11** is assumed to instruct the driver circuit **17** to pluck the reed **48*a*** shown in FIG. **18**A. The flat coil **44** has not been energized so as to keep the swingable arm **43** horizontal. The tip of the blade **45** stands upright, and is spaced from the rotary pick **46**.

The driver circuit **17** determines the pulse width to be required for the target loudness, and the pulse width modulator PWM supplies the driving signal with the pulse width to be required for the target loudness to the flat coil **44**. When the current flows through the flat coil **44**, the magnetic force is exerted on the flat coil **44**, and gives rise to rotation of the swingable arm **43** in the counter clockwise direction. The blade **45** is brought into contact with the flat back surface **46*a*1** of the rotary pick **46**, and pushes it. The rotary pick **46** is driven for rotation over 90 degrees as indicated by arrow AR5 (see FIG. **19**), and plucks the reed **48*a*** with the claw **46** spaced 180 degrees from the claw **46** pushed by the blade **45**. The reed **48*a*** vibrates as indicated by arrow AR**6**, and generates the tone. The disk **46*b*** is spaced from the vibrating reed **48*a***, and the claws **46*a*** are out of the trajectory of the vibrating reed **48*a***. Thus, the rotary pick **46** does not interfere with the vibrating reed **48*a***.

The driver circuit **20**Ab removes the driving signal from the flat coil **44**. Then, the self weight causes the swingable arm **43**, flat coil **44** and blade **45** to return to the rest position shown in FIG. **18**A. The ratchet **53** prevents the rotary pick **46** from the reverse rotation.

In this instance, the swingable arms **43** and flat coils **44** occupy the space under the array of reeds **48**, and the blades **45** and the rotary picks **46** are provided in the proximity of the tips of the reeds **48*a***. The space to be additionally required for the vibrating reeds **48*a*** is the gap between the claws **46*a***. Thus, the array of reeds **48** and player's fingers **20**E are compactly packed in a housing of the musical instrument without interference with the vibrating reeds **48**. This results in the compact musical instrument.

Moreover, the controller **20**Ab independently energizes the solenoid-operated flat actuators FLAT**1** on the basis of the music data codes so that the automatic player performs any piece of music. If plural tones are to be concurrently produced for a chord, the controller **20**Ab concurrently energizes the associated solenoid-operated flat actuators FLAT**1**.

The flat coils **44** are used in the player's fingers **20**E. The flat coils **44** are so thin that the manufacturer can arrange the player's fingers **20**E at small pitches. Thus, the player's fingers **20**E plucks the reeds **48*a*** of the comb-like array **48**.

The claws **46*a*** are arranged on the disk **46*b*** at intervals, and the intervals are wide enough to permit the associated reed **48*a*** to vibrate without interference. The vibrations are stable, and, accordingly, the tones are clear.

The rotary pick **46** includes more than one claws **46*a***. One of the claws **46*a*** is pushed with the blade **45**, and another claw **46*a*** plucks the reed **48*a***. The roles are sequentially changed among the plural claws **48*a***. This results in the simple structure of the player's fingers.

FIGS. **20**A and **20**B show another player's finger **20**F incorporated in an automatic player, which in turn forms a part of a musical instrument. The player's fingers **20**F are respectively associated with the reeds **48*a***, and, are selectively energized by the controller **20**Ab (see FIG. **16**). Each of the player's fingers **20**F includes the solenoid-operated flat actuator FLAT**1**, a pick **51**, a string **52** and a guide block **52*a***. The solenoid-operated flat actuator FLAT**1** is similar to that of the player's finger **20**E, and the component parts are labeled with same references designating corresponding component parts in the player's finger **20**E without detailed description.

The blade **45** and rotary pick **46** are replaced with the pick **51**. The pick **51** pick **51** has a stem portion **51*a*** and a head portion **51*b***, and the stem portion **51*a*** is rotatably connected at the lower end thereof to the free end portion **43*a*** of the swingable arm **43** by means of a pin **56**. For this reason, the pick **51** is rotatable in the clockwise direction and counter clockwise direction. The head portion **51*b*** has a rounded front surface **51*b*1**, and the rounded front surface **51*b*1** smoothly slides on the tapered tip **48*b*** of the associated reed **48*a***. The spring **52** is connected at one end thereof to the head portion **51*b*** and at the other end thereof to a stationary member of the musical instrument such as an inner surface of the guide block **52*a***. While the swingable arm **43** is staying in the gap between the yokes **42**, the spring exerts a negligible amount of elastic force on the pick **51** so that the pick **51** keeps its attitude upright. The spring **52** increases the elastic force together with the rotation of the swingable arm **43** in the counter clockwise direction.

Guide pins **57** sidewardly project from the side surfaces of the head portion **51*b***. Though not shown in the figures, guide grooves are formed in the side walls of the guide block **52*a***, and the pins **57** are moved along the guide grooves. The guide grooves for the upward motion are routed differently from the guide grooves for the downward motion. While the pins **57** are moved along the guide grooves for the upward motion, the rounded front surface **51*b*1** is brought into contact with the tapered tip **48*b***, makes the rounded front surface **51*b*1** slide on the tapered tip **48*b***, and escapes form the tapered tip **48*b***. Then, the reed **48*a*** vibrates for generating a tone. After the escape, the pins **57** enter the guide grooves for the downward motion. While the pins **57** are moving along the guide grooves for the downward motion, the pick **51** is inclined as indicated by **51**(**P1**), and passes in front of the vibrating reed **48*a*** without any interference. Thus, the trajectory of the head portion **51*b*** is defined by the guide grooves.

The pick **51** is staying at the rest position **P0**. The driver circuit **17** is assumed to energize the solenoid-operated flat actuator FLAT**1** during performance of the automatic player. The swingable arm **43** is driven for rotation in the counter clockwise direction, and the pins **57** keep the pick **51** tangential with the longitudinal direction of the swingable arm **43** against the elastic force of the spring **52**. The rounded front surface **51*b*1** is brought into contact with the tapered tip **48*b***, and warps the reed **48*a***. The guide grooves and pins **57** make the pick **51** inclined as indicated by **51**(**P1**), and the pick **51** escapes from the tapered tip **48*b*** of the reed **48*a***. The rounded front surface **51*b*1** smoothly slides on the tapered tip **48*b*** so that the head portion **51*b*** is never caught on the tapered tip **48*b***.

The driving circuit **17** removes the driving signal from the flat solenoid **44**, and the self-weight and elastic force cause the swingable arm **43**, flat solenoid **44** and pick **51** to pull down. Since the pins **57** are moved along the guide grooves for the downward motion, the head portion **51*b*** passes the space in front of the vibrating reed **48*a***. Thus, the pick **51** does not interfere with the vibrating reed **48*a***.

As will be understood, the player's fingers **20**F achieve all the advantages of the player's fingers **20**E. Moreover, the picks **51** are simpler than the rotary picks **46** so that the production cost is reduced. The guide block **52*a***, pins **57** and springs **52** surely shunt the picks **51** to the downward trajectory, and prevent the vibrating reeds **48*a*** from the interference. This results in the clear tones.

FIG. **21** shows another modification of the musical instrument. The musical instrument shown in FIG. **21** is similar to the musical instrument shown in FIG. **17** except that rotary picks **66** are driven for rotation by solenoid-operated cylindrical actuators CYL**1**. The musical instrument comprises plural reeds **61**, a hub **63**, a controller (not shown) and player's fingers **20**G. The reeds **61** have respective boss portions **62** fixed to the hub **63**, and radially project form the hub **63**. In this instance, twenty reeds **61** are arranged around the hub **63**, and the hub **63** has a disk shape. In other words, the distance from the center of the hub **63** to the periphery thereof is constant. The reeds **61** are different in length and width from one another depending upon pitches of tones to be generated. The distance between the center of the hub **62** and the player's fingers **20**G is varied depending upon the length of the reeds **61**. However, the distance between the center of the hub **63** and the periphery may be varied together with the angle so that the player's fingers **20**G are disposed on a virtual circle.

The player's fingers **20**G are fixed to brackets **64**/**65**, and are respectively associated with the reeds **61** for plucking. The player's finger **20**G includes the solenoid-operated cylindrical actuator CYL**1**, a rotary pick **66**, a head block **71** and a combination of cam plates and cam springs **76**/**75** serving as a brake unit. A solenoid coil **68**, a plunger **70**, a plunger spring **69** and yoke **64**/**65** form in combination the solenoid-operated cylindrical actuator CYL**1**. The yoke **64**/**65** has a pair of ring plates **64**/**65**, and yoke spacers **67** are provided between the ring plates **64** and **65**. The yoke **64**/**65** is bolted to the hub **63**, and is shared among all the solenoid-operated cylindrical actuators CYL**1**. The solenoid coils **68** are inserted into the space between the ring plates **64** and **65**, and the plungers **70** are slidably received in the cylindrical spaces defined in the associated solenoid coils **68**. Caps **65***a*/**65***b* are bolted to the ring plate **64** and **65** at intervals, and the caps **65***a* offer extension spaces to the associated plungers **70**, respectively. Cushion sheets **72** and **73** are disposed at the bottoms of the caps **65***a*/**65***b*, and define the upper dead points and the lower dead points for the associated plungers **70**. The cushion sheets **72** and **73** absorb the impact of the plunger **70**, and prevent the solenoid-operated actuator CYL**1** from noise.

The plunger springs **69** are attached to the ring plate **65**, and always urge the associated plungers **70** upwardly. When current flows through the coil **68**, magnetic filed is created, and the plunger **70** is downwardly pulled. On the other hand, the magnetic field is removed, the plunger spring **69** pushes the plunger **70** upwardly.

The head block **71** is fixed to an upper thin portion of the plunger **70**, and a ring space **70***a* takes place between the head block **71** and the remaining thick portion of the plunger **70**. The claws **66***a* of the associated rotary pick **66** selectively slide into the ring space **70***a*, and are brought into contact with a part **71***a* of the head block **71** when the plunger returns to the upper dead point. Thus, the head block **71** serves as a pusher.

The rotary pick is rotatably supported between the tip of the reed **61** and the solenoid-operated cylindrical actuator CYL**1**. The rotary pick **66** is similar to the rotary pick **46**, and has plural claws **66***a*, which radially project at regular intervals. The brake units are respectively associated with the rotary picks **66**. The cam plates **76** are fixed to the sides surface of the rotary pick **66**, and the cam springs **75** are fixed to the cap **65***a* on both sides of the rotary pick **66**. Each cam plate **76** has four corners, and the cam springs, which are leaf springs made of metal, are urged to be always held in contact with the cam plates **76**. The brake unit **76**/**75** permits the associated rotary pick **66** to be rotated in the clockwise direction. However, the brake unit **76**/**75** prohibits the rotary pick **66** from the rotation in the counter clockwise direction.

The player's finger **20**G plucks the associated reed **61** as shown in FIGS. **23**A to **23**H. FIG. **23**A shows the plunger **71** at the upper dead point, and the claw **66***a***1** is resting in the ring space **70***a*. The controller is assumed to energize the coil **68**. The plunger **70** starts the downward motion against the elastic force of the spring **69**. The inner portion **71** a is brought into contact with the claw **66***a***1** as shown in FIG. **23**B. However, the claw **66***a***3** is still spaced from the tip of the reed **61**.

The plunger **70** is further moved downwardly, and gives rise to the rotation of the rotary pick **66** in the clockwise direction. The cam plates **76** are rotated against the elastic force of the cum springs **75** exerted on the corners, and the claw **66***a***3** plucks the reed **61** as shown in FIG. **23**C. The reed **61** vibrates, and generates a tone. The plunger **70** is further moved downwardly, and the rotary pick **66** is rotated in the clockwise direction. However, the next claw **66***a***2** has not reached the vibrating reed **61**, and the rotary pick **66** does not interfere with the vibrating reed **61** as shown in FIG. **23**D. When the plunger **70** reaches the lower dead point, the next claw **66***a***2** is still spaced from the vibrating reed **61**.

The magnetic field is removed from the solenoid-operated cylindrical actuator CYL**1**, and the plunger spring **69** urges the plunger **70** in the upward direction. Although the head block **71** pushes the claw **66***a***4**, the cam springs **75** and cam plates **76** do not permit the rotary pick **76** to be rotated in the counter clockwise direction, because the braking force is larger than the friction between the head block **71** and the claw **66***a***4** (see FIG. **23**E).

FIGS. **23**F and **23**G illustrate the plunger **70** on way to the upper dead point. However, the cam plates **76** and cam springs **75** prevent the rotary pick **66** from the rotation in the counter clockwise direction. When the plunger **70** reaches the upper dead point, the head block **71** is spaced from the claw **66***a***4**, which is to be pushed during the next downward motion of the plunger **70**, and the cam springs **75** slightly rotate the rotary pick **66** in the clockwise direction. As a result, the next claw **66***a***4** slides into the ring space as shown in FIG. **23**H.

The musical instrument achieves all the advantages of the above-described musical instrument according to the present invention. Moreover, the player's fingers **20**G pluck the associated reeds **61** surer than the player's fingers **20**E, because the head blocks **71** faithfully reciprocate the given trajectories. The brake unit **75**/**76** not only prevents the rotary pick **66** from the reverse rotation but also keep the claws **66***a* at the same position in the ring space **70***a* after the spring **69** spaces the head block **71** from the claws **66***a*. The magnetic force exerted on the plunger **70** is constant, and the head block **71** exerts the constant force on the claw **66***a*. This results in the clear tones at constant loudness.

FIGS. **24** and **25**A show another musical instrument according to the present invention. The musical instrument comprises an array **82** of reeds **83** and an automatic player. The automatic player includes plural player's fingers **20**H and a controller, which is same as the controller **20**Ab shown in FIG. **16**.

The array **82** is like a comb, and the reeds **83** project in parallel like the teeth of the comb. The reeds **83** are different in length and width so that tones different in pitch are generated by the reeds **83**. The array **82** is mounted on a block, and is fixed to the base plate **81** by means of bolts.

Solenoid-operated flat actuators FLAT**2** are employed in the player's fingers **20**H, and include permanent magnet plates **84**, yokes **85**, flat coils **86** and swingable arms **88**. The flat coils **86** are respectively attached to the side surfaces of the swingable arms **88**. The yokes **85** are taller than the permanent magnet plates **84**, and the yokes **85** and permanent magnet plates **84** are alternated with one another. For this reason, gaps take place between the yokes **85**, and the swingable arms **88** are resting in the gaps together with the flat coils **86** as shown in FIG. **25**B.

The arms **88** are swingably connected at the rear ends thereof to a shaft **87**, which in turn is supported by the base plate **81**. Arm springs **89** are provided for the swingable arms **88**, respectively, and always urge the swingable arms

88 in the clockwise direction in FIG. **25**A so that free end portions of the arms **88** are rested on the lower surface of the upper stopper **90**, which is fixed to the base plate **81**, without any magnetic field. The rest positions of the swingable arms **88** are indicated by **88(P0)**, and the upper surfaces of the swingable arms **88** are held in contact with the lower surface of the upper stopper **90** at the rest positions. A lower stopper **95** is further fixed to the base plate **81**, and receives the free end portions of the arms **88** at the end of the rotation in the counter clockwise direction. **88(P1)** is indicative of the swingable arm **88** on the way to the lower stopper **95**. Guide plates **94** (see FIG. **24**) are provided on both sides of each swingable arm **88**, and define the trajectory of the associated swingable arm **88**. For this reason, the trajectory of the swingable arm **88** is perpendicular to the upper surface of the base plate **81**.

The swingable arms **88** are respectively formed with notches **88***b* in the free end portions as shown in FIG. **25**C. Rotary picks **92** are rotatably connected to a shaft **91**, which is supported at both end portions thereof by the base plate **81**. A brake unit **93/96** is associated with each of the rotary pick **92**. The rotary pick **92** and brake unit **93/96** are same as those of the music player shown in FIGS. **21** to **23**H. For this reason, detailed description is omitted for the sake of simplicity.

The claws **92***a* selectively enter the notch formed in the associated swingable arm **88**. While the swingable arm **88** is rotating in the counter clockwise direction, the edge **88***c*, which partially defines the notch **88***b*, presses the claw **92***a*, and gives rise to rotation of the rotary pick **92**. When the rotary pick **92** is rotated over a predetermined angle, the brake unit **93/96** stops the rotary pick **92**, and does not permit the rotary pick **92** from the reverse rotation.

Assuming now that the controller **20**Ab energizes the flat coil **86** shown in FIG. **25**A, the magnetic force is exerted on the flat coil **86** and, accordingly, the swingable arm **88** so as to give rise to the rotation of the swingable arm **88** about the shaft **87** in the counter clockwise direction against the elastic force of the arm spring **89**. The swingable arm **88** starts the rotation at the rest position **88(P0)**, and is moved on the trajectory toward the lower stopper **95**.

The edge **88***c* is brought into contact with the claw **92***a*, and gives rise to the rotation of the rotary pick **92** in the clockwise direction against the elastic force of the cam springs **93**. Subsequently, the claw **92***a*, which is at the opposite position 180 degrees spaced from the claw **92***a* pressed by the edge **88***c*, is brought into contact with the associated reed **83**, and plucks it. The reed **83** vibrates, and generates the tone. When the swingable arm **88** reaches the lower stopper **95**, the reed **83** is vibrating in the space between the claw **92***a* and the next claw **92***a* so that the rotary pick **92** does not interfere with the vibrating reed **83**.

When the magnetic force is removed from the flat coil **86**, the arm spring **89** rotates the swingable arm **88** in the clockwise direction. Although the friction between the claw **92***a* and the swingable arm **88** urges the rotary pick **92** in the counter clockwise direction, the brake unit **93/96** does not permit the rotary pick **92** from the reverse rotation. The swingable arm **88** reaches the upper stopper **90**, and the cam springs **93** urge the rotary pick **92** in the clockwise direction so that the next claw **92***a* enters the notch **88***b*.

The musical instrument achieves the advantages by virtue of the solenoid-operated flat actuators FLAT**2**, rotary picks **92** and brake units **93/96**. Moreover, the swingable arms **88** are stable and large in mechanical strength so that the musical instrument is durable.

FIGS. **26**A and **26**B show another musical instrument according to the present invention. The musical instrument comprises an automatic player and a daisy reed wheel **113**, which forms a part of a tone generator. The automatic player includes plural player's fingers **20I** and the controller **20**Aa (see FIG. **12**). The daisy reed wheel **113** has reeds **114** radially outwardly projecting from the circular periphery of a disk **113***a*, and the player's fingers **20I** are disposed in the proximity of the tips of the reeds **114**. In this instance, twenty-four reeds project from the disk **113***a*, and are different in length and width from one another for generating tones different in pitch.

The player's finger **20I** includes a solenoid-operated actuator CLY**2**, a rotary pick **112**, a pusher **122** and a spring **125**. The solenoid-operated actuator CLY**2** is similar to the solenoid-operated **21**C (see FIG. **14**), and includes a coil **121**, a bobbin **123***a*, a bottom yoke **123***b* and a plunger **126**. The pusher **122** has a lower end portion **122***a*, which is rotatably connected to a pin **124**, and the string **125** is connected at one end thereof to the upper end portion of the pusher **122** and at the other end thereof to the bottom yoke **123***b*. While the plunger **126** is staying at the rest position, the spring **125** exerts a negligible amount of elastic force on the pusher **122**. However, the elastic force is increased together with the stroke of the plunger **126** from the rest position. Since the bottom yoke **123***b* has the inward portion upwardly project from the remaining portion, pusher **122** is inwardly inclined in the magnetic field. While the plunger **126** is projecting upwardly, the pusher **122** is spaced from the bottom yoke **123***b*, and the magnetic force exerted on the pusher **122** is decreased. When the elastic force exceeds the magnetic force, the pusher **122** is outwardly inclined.

The rotary pick **112** is rotatably supported by the shaft **111** between the tip of the associated reed **114** and the solenoid-operated actuator CLY**2**. The rotary pick **112** has plural claws **112***a* spaced at regular intervals, and a ratchet **115** is provided for the rotary pick **112**. The ratchet **115** permits the rotary pick **112** in the counter clockwise direction in FIG. **26**B.

The controller **20**Aa is assumed to energize the solenoid-operated actuator CLY**2**, current flows through the coil **121**, and magnetic field is created. The pusher **122** is inwardly inclined as indicated by **122(P0)**, and the plunger **126** starts to project upwardly. The pusher **122** is brought into contact with the claw **112***a*, and gives rise to rotation of the rotary pick **112** in the counter clockwise direction. Another claw **112***a* warps the reed **114**, and escape from the reed **144**. Then, the reed **114** vibrates, and generates the tone. The ratchet **115** stops the rotary pick **112**. When the elastic force exceeds the magnetic force, the pusher **122** escapes from the claw **112***a*.

When the pusher **122** reaches the upper dead point **122(P1)**, the controller **20**Aa removes the magnetic field from the solenoid-operated actuator CLY**2** so that any magnetic force is not exerted on the pusher **122**. The spring **125** outwardly inclines the pusher **122** as indicated by **122(P2)**, and the plunger **126** is retracted into the bobbin **123***a*. When the plunger **126** reaches the lower dead point, the pusher **122** returns to the rest position **122(P3)**. Thus, the pusher **122** returns to the rest position without any interference with the claw **112***a*.

The musical instrument achieves the advantages by virtue of the rotary pick **112** and solenoid-operated actuator CLY**2**. The player's fingers **20I** shown in FIG. **26**B do not set any limit to the positions to be occupied. Other player's fingers may be provided over the rotary picks **112**.

FIGS. 27A, 27B and 28 show another musical instrument according to the present invention. The musical instrument is also broken down into a tone generator and an automatic player. The tone generator includes plural reeds 135 arranged like a comb on a base plate 146. The reeds 135 project from a boss portion 137 in parallel to one another. In the following description, term "front" is indicative of a relative position close to the right side of the paper where FIGS. 27A and 27B are drawn. For this reason, the reeds 135 project frontward.

On the other hand, the automatic player includes the controller 20Aa and plural player's fingers 20J, which share a guide frame 136*a* on the base plate 146 and a yoke 131 on a base plate 130 spaced from the base plate 146. The guide frame 136*a* is fixed to the base plate 146, and is provided over the reeds 135. The player's fingers 20J are respectively associated with the reeds 135.

Each of the player's fingers 20J includes a solenoid-operated actuator CYL3, a flexible tube 134, a wire 144, a pusher 139, a rotary pick 140 and a ratchet 142. The yoke 131 is fixed to the base plate 130, and is shared among the solenoid-operated actuators CYL3. Coils 132 are retained by the yoke 131, and are partially overlapped with one another. For this reason, plungers 133, which are respectively inserted into the coils 132, are exposed to the rear surface of the yoke 131 as shown in FIG. 27B.

The wire 144 is inserted into the flexible tube 134, and is connected at one end thereof to the associated plunger 133 and at the other end to the pusher 139. The wire 144 is flexible, and is strong enough to transmit the force to the pusher 139. A piano wire may be used as the wire 144. Even if the flexible tube 134 is winded, the wire 144 can slide inside the winded tube 134.

The guide frame 136*a* has two guide blocks 136 and 146 and a base plate 143. The guide blocks 136/145 are as wide as the array of reeds 135. The guide block 145 is frontward spaced from the other guide block 136, and are fixed to the base plate 143. Through-hole are formed in the guide block 136 for the flexible wires 144, and grooves are formed in the other guide block 145 for the pushers 139. The flexible wires 144 pass through the through-holes, and the pushers 139 are slidably received in the groove. The pushers 139 frontward project from the front end surfaces of the guide block 145. When the plungers 133 project from the yoke 131, the plungers 133 push the flexible wires 144, and the flexible wires 144 transfer the force to the associated pushers 139. As a result, the pushers 139 frontward project from the guide block 145. The pushers 139 are made from a relatively thin metal plate, and are elastically deformable.

The shaft 141 is arranged in parallel to the guide block 145, and the rotary picks 140 are rotatably supported by the shaft 141 at intervals. The rotary picks 140 are close to the associated pushers 139 and associated reeds 135. The ratchets 142 permit the associated rotary picks 140 in the clockwise direction in FIGS. 29A and 29B. Each of the rotary picks 140 has plural claws 140*a* spaced at regular intervals. In this instance, four claws 140*a* radially project at intervals of 90 degrees.

Assuming now that the controller 20Aa energizes the solenoid-operated actuator shown in FIG. 29A, the current flows through the coil 132, and creates magnetic field. Then, the plunger 133 frontward projects from the yoke 131, and the force F2 is transmitted from the plunger 133 through the flexible wire 144 to the pusher 139. The pusher 139 frontward projects from the guide block 145, and is brought into contact with one of the claws 140*a*. Although the tip of the pusher 139 is deformed (see FIG. 29B), the force F2 gives rise to the rotation of the rotary pick 140 over 90 degrees. While the rotary pick 140 is rotating, another claw 140*a* plucks the reed 135 so that the reed 135 vibrates for generating a tone. The claw 140*a*, which has plucked the reed 135, reaches the position occupied by the claw 140*a* previously pushed by the pusher 139.

When the controller 20Aa removes the magnetic field, a return spring (not shown) moves the plunger 133 backwardly, and the plunger 133 is retracted into the yoke 131. The plunger 133 pulls the flexible wire 144 and the pusher 139. The pusher 139 slides on the claw 140*a* backwardly. However, the ratchet 142 does not permit the rotary pick 140 to rotate in the counter clockwise direction. The tip of the pusher 139 is warped, and returns to the rest position.

The musical instrument achieves the advantages by virtue of the rotary wheel 140. Moreover, the solenoid-operated actuators CYL3 are connected to the pushers 139 by means of the flexible wires 144 so that the manufacturer can locate the base plates 130 and 146 at the optimum positions. Thus, the flexible wires 144 enhance the design flexibility.

The yoke 131 may be separated into yokes, which are incorporated in the solenoid-operated actuators CYL3, respectively. The yoke may be replaced with a pair of plates. In this instance, each of the coils 132 is sandwiched between the plates.

In the musical instrument described hereinbefore, the pusher 139 projects from the guide block 145 for exerting the force on the claw 140*a* of the rotary pick 140. Another musical instrument may have a reciprocal rod 153 instead of the pusher 139 as shown in FIGS. 30A and 30B. In these figures, reference numeral 155 designates one of the reeds of a comb-like array, and rotary picks 156 are rotatably supported in the proximity of the associated reeds 155. The ratchets 158 are provided on the rotary picks 156, and permit the associated rotary picks 156 in the counter clockwise direction over the predetermined angle. Though not shown in the figures, the solenoid-operated actuators CYL3 are connected through flexible wires 151 to the reciprocal rods 153, and a guide block 151 slidably supports the flexible wires 152. Arms 154 are swingably connected to the tips of the reciprocal rods 153, and springs (not shown) always urge the swingable arms 154 in the counter clockwise direction. However, stoppers (not shown) do not allow the arms 154 to rotate beyond the positions shown in FIG. 30A. While the controller 30Aa is keeping the solenoid-operated actuators CYL3 non-magnetized, the reciprocal rods are staying at the rest positions spaced from the guide block 151, and the tip of the reed 155 is in the gap between the claws 156*a* as shown in FIG. 30A.

The solenoid-operated actuator CYL3 is assumed to pull the flexible wire 152. The reciprocal rod 153 is moved in the direction indicated by F3, and the arm 154 gives rise to the rotation of the rotary pick 156 in the counter clockwise direction. The ratchet 158 permits the rotary pick 156 to rotate over the predetermined angle, and another claw 156*a* plucks the reed 155 as shown in FIG. 30B. The reed 155 vibrates, and generates a tone.

The controller 20Aa removes the magnetic field from the solenoid-operated actuator CYL3. Then, the spring (not shown) moves the flexible wire 152 and the reciprocal rode 153 in the direction F2. Although the claw 156*a* is the obstacle against the arm 154 moved in the direction F2, the arm 154 is folded against the elastic force of the spring, and returns to the rest position. Even though the arm 154 slides on the claw 156*a*, the ratchet 158 keeps the rotary pick 156 stable. Thus, the player's finger achieves all the advantages of the player's finger 20J.

The pusher **139** may be replaced with a foldable pusher **157** shown in FIG. **30**C. The ratchet **159** permits the rotary pick **156** to rotate in the counter clockwise direction, and the foldable pusher **157** is connected through the flexible wire **152** to the plunger of the solenoid-operated actuator CYL**3**. A spring urges the foldable pusher **157** at a slightly raised attitude at the rest position **157(P0)**.

The plunger **133** is assumed to project from the yoke **131**. The flexible wire **152** and the foldable pusher **157** project from the rest position **157(P0)** to the position **157(P1)**, and gives rise to the rotation of the rotary pick **156** in the counter clockwise direction. The claw **156***a* plucks the reed **155** for vibrations.

When the controller **20**Aa removes the magnetic field from the solenoid-operated actuator CYL**3**, the flexible wire **152** and foldable pusher **157** are moved in the direction F**3**. The foldable pusher **157** is stretched against the elastic force of the spring as indicated by **157(P2)**, and passes under the claw **156***a* as indicated by **157(P3)**.

As will be understood from the foregoing description, the musical instruments implementing the second embodiment have the following advantages. The musical instruments equipped with the rotary picks make the reeds vibrate with the claws, and the reeds vibrate in the gap between the claws. This results in the natural vibrations without interference. In other words, clear tones are generated from the vibrating reeds.

The rotary picks change themselves between the plucking positions and the shunt positions through the rotation thereof Any additional space is not required for leaving the reeds vibrating. Moreover, the rotary picks per se require narrow space. Thus, the rotary picks are conducive to the compactness of the musical instruments.

Another advantage by virtue of the rotary picks is promptness. The rotary picks require the rotation over the predetermined angle for changing their positions. Even if the controller quickly changes the plunger of the solenoid-operated actuator between the projecting position and the retracted position, the rotary pick can respond to the quick motion so that the musical instrument reproduces the repetition on the certain reed.

The reeds are replaceable with another sort of vibrating members such as, for example, strings or tone bars. Although the strings are plucked, the tone bars are beaten with mallets. In this instance, the player's fingers selective beat the tone bars.

Third Embodiment

Prototype

FIGS. **31**, **32**, **33**A and **33**B show a musical instrument embodying the present invention. The musical instrument is categorized in the music box. The musical instrument largely comprises a tone generator and an automatic player as similar to the first and second embodiments. The tone generator is implemented by a comb-like array **48**K of reeds **48***a*, and the automatic player comprises a controller **20**Ak and player's fingers **20**K. The comb-like array **48**K of reeds **48***a*, controller **20**Ak and player's fingers **20**K are similar in structure to the array **48** of reeds **48**, controller **20**Ab and player's fingers **20**E shown in FIGS. **16** and **17**. For this reason, component circuits of the controller **20**Ak and component parts of the comb-like array **48**K and player's fingers **20**K are labeled with references designating corresponding circuits of the controller **20**Ab and corresponding parts of the array **48** and player's finger **20**E without detailed description.

Assuming now that a user requests the automatic player to perform a piece of music, the central processing unit **11** sequentially accesses music data codes stored in the memory **13**, and instructs the driver circuit **17** to selectively energize the solenoid-operated flat actuators FLAT**1** While the central processing unit **11** is sequentially processing the music data, the central processing unit **11** is assumed to instruct the driver circuit **17** to pluck the reed **48***a* shown in FIG. **33**A. The flat coil **44** has not been energized so as to keep the swingable arm **43** horizontal. The tip of the blade **45** stands upright, and is spaced from the rotary pick **46**.

The driver circuit **17** determines the pulse width to be required for the target loudness, and the pulse width modulator PWM supplies the driving signal with the pulse width to be required for the target loudness to the flat coil **44**. When the current flows through the flat coil **44**, the magnetic force is exerted on the flat coil **44**, and gives rise to rotation of the swingable arm **43** in the counter clockwise direction. The blade **45** is brought into contact with the flat back surface **46***a***1** of the rotary pick **46**, and pushes it. The rotary pick **46** is driven for rotation over 90 degrees as indicated by arrow AR**5** (see FIG. **34**), and plucks the reed **48***a* with the claw **46** spaced 180 degrees from the claw **46** pushed by the blade **45**. The reed **48***a* vibrates as indicated by arrow AR**6**, and generates the tone. The disk **46***b* is spaced from the vibrating reed **48***a*, and the claws **46***a* are out of the trajectory of the vibrating reed **48***a*. Thus, the rotary pick **46** does not interfere with the vibrating reed **48***a*.

The driver circuit **20**Ab removes the driving signal from the flat coil **44**. Then, the self weight causes the swingable arm **43**, flat coil **44** and blade **45** to return to the rest position shown in FIG. **33**A. The ratchet **53** prevents the rotary pick **46** from the reverse rotation.

In this instance, the controller **20**Ak selectively energizes the flat coils FLAT**1** for plucking the reeds **48***a* with the claws **46***a*. This means that the plural rotary picks **46** can concurrently pluck the reeds **48***a* for producing a chord. The rotary pick **46** is rotated over only the predetermined angle for plucking the reed **48***a*. The rotary pick **46** is responsive to quick repetition so that the automatic player can perform any complicated passage.

The solenoid-operated flat actuators FLAT**1** give rise to the rotation of the associated swingable arms **43** without any physical contact between the flat coils **44** and the yokes **42** and between the arms **43** and the yokes **42**. The arms **42** and flat coils **44** are less worn out. Thus, the player's fingers **20**K are durable.

The solenoid-operated flat actuators FLAT**1** occupy the space under the reeds **48***a*. In other words, the solenoid-operated flat actuators FLAT**1** are overlapped with the comb-like reed array **48**K. This results in the compact musical instrument.

The automatic player can perform various passages without changing the hardware. The user needs to load a piece of music data into the memory **13**. Thus, the automatic player can answer all the user's requests in so far as the user prepares the pieces of music data.

The solenoid-operated flat actuators FLAT**1** are desirable for the comb-like reed array **48**K, because the manufacturer can arrange them at small pitches. Even though the reeds **48***a* are extremely narrow, the solenoid-operated flat actuators FLAT**1** are provided in the proximity of the tips of the reeds **48***a*.

The rotary picks **46** are desirable for the simple structure of the automatic player, because the claws **46***a* not only receive the force from the blades **45** but also pluck the reeds **48***a*.

Another attractive point of the rotary picks **46** is smoothly to change itself between the plucking position and the shunt position. This results in that the reeds **48***a* generate clear tones. When the rotary pick **46** is rotated over the predetermined angle, the rotary pick **46** plucks the reed **48***a* with one of the claws **48***a*, and stops at the angular position in which the reed **48***a* freely vibrate between the claws **46***a*. The rotary pick **46** is required for the rotation over the predetermined angle. The claws **46***a* do not interfere with the vibrating reed **48***a*, because the claws **46***a* are spaced wide enough to permit the reed **48***a* to vibrate in the gap therebetween.

The solenoid-operated flat actuators FLAT1 are disposed at any space, because the rotary picks **46** pluck the associated reeds **48***a*. The combination between the rotary picks **46** and the solenoid-operated flat actuators FLAT1 enhances the design flexibility.

The flat coils **44** may be alternated with the yokes **42**. In this instance, the permanent magnet plates **41** are attached to the swingable arms **43**. A large magnet may create a strong magnetic field for all the flat coils **44**.

Modifications

FIGS. **35**A and **35**B show a modification of the player's finger. The player's finger **20**L. The player's fingers **20**L are similar to the player's fingers **20**F so that the component parts of the player's finger **20**L are labeled with the component parts of the player's finger **20**F without detailed description.

The guide block **52***a* and pin **57** keep the trajectory of the pusher **51** stable so that the pusher **51** does not interfere with the vibrating reed **48***a*. The player's finger **20**F has the advantages by virtue of the solenoid-operated flat actuators FLAT1.

FIGS. **36**, **37**A and **37**B show a modification of the musical instrument. The musical instrument is broken down into a tone generator and an automatic player. The tone generator is implemented by a daisy reed wheel, and automatic player includes a controller and player's fingers **20**M. The daisy reed wheel, controller and player's fingers **20**M are similar to those of the musical instrument shown in FIGS. **21**, **22**A and **22**B. For this reason, the component parts are labeled with references designating corresponding parts of the musical instrument shown in those figures.

The player's finger **20**M plucks the associated reed **61** as shown in FIGS. **38**A to **38**H. FIG. **38**A shows the plunger **71** at the upper dead point, and the claw **66***a***1** is resting in the ring space **70***a*. The controller is assumed to energize the coil **68**. The plunger **70** starts the downward motion against the elastic force of the spring **69**. The inner portion **71***a* is brought into contact with the claw **66***a***1** as shown in FIG. **38**B. However, the claw **66***a***3** is still spaced from the tip of the reed **61**.

The plunger **70** is further moved downwardly, and gives rise to the rotation of the rotary pick **66** in the clockwise direction. The cam plates **76** are rotated against the elastic force of cum springs **75** exerted on the corners, and the claw **66***a***3** plucks the reed **61** as shown in FIG. **38**C. The reed **61** vibrates, and generates a tone. The plunger **70** is further moved downwardly, and the rotary pick **66** is rotated in the clockwise direction. However, the next claw **66***a***2** has not reached the vibrating reed **61**, and the rotary pick **66** does not interfere with the vibrating reed **61** as shown in FIG. **38**D. When the plunger **70** reaches the lower dead point, the next claw **66***a***2** is still spaced from the vibrating reed **61**.

The magnetic field is removed from the solenoid-operated cylindrical actuator CYL1, and the plunger spring **69** urges the plunger **70** in the upward direction. Although the head block **71** pushes the claw **66***a***4**, the cam springs **75** and cam plates **76** do not permit the rotary pick **76** to be rotated in the counter clockwise direction, because the braking force is larger than the friction between the head block **71** and the claw **66***a***4** (see FIG. **38**E).

FIGS. **38**F and **38**G illustrate the plunger **70** on way to the upper dead point. However, the cam plates **76** and cam springs **75** prevent the rotary pick **66** from the rotation in the counter clockwise direction. When the plunger **70** reaches the upper dead point, the head block **71** is spaced from the claw **66***a***4**, which is to be pushed during the next downward motion of the plunger **70**, and the cam springs **75** slightly rotate the rotary pick **66** in the clockwise direction. As a result, the next claw **66***a***4** slides into the ring space as shown in FIG. **38**H.

The automatic players **20**M have the advantages by virtue of the rotary picks **66**. Moreover, the player's fingers **20**M pluck the associated reeds **61** surer than the player's fingers **20**K, because the head blocks **71** faithfully reciprocate the given trajectories. The brake unit **75**/**76** not only prevents the rotary pick **66** from the reverse rotation but also keep the claws **66***a* at the same position in the ring space **70***a* after the spring **69** spaces the head block **71** from the claws **66***a*. The magnetic force exerted on the plunger **70** is constant, and the head block **71** exerts the constant force on the claw **66***a*. This results in the clear tones at constant loudness.

FIGS. **39**, **40**A, **40**B and **40**C show another musical instrument according to the present invention. The musical instrument largely comprises a tone generator and an automatic player. The tone generator is implemented by a comb-like reed array, and the automatic player includes a controller and player's fingers **20**N. The comb-like reed array, controller and player's fingers are similar to those of the musical instrument shown in FIGS. **24**, **25**A, **25**B and **25**C. For this reason, the component parts are labeled with same references designating corresponding parts shown in those figures without detailed description.

Assuming now that the controller energizes the flat coil **86** shown in FIG. **40**A, the magnetic force is exerted on the flat coil **86** and, accordingly, the swingable arm **88** so as to give rise to the rotation of the swingable arm **88** about the shaft **87** in the counter clockwise direction against the elastic force of the arm spring **89**. The swingable arm **88** starts the rotation at the rest position **88(P0)**, and is moved on the trajectory toward the lower stopper **95**.

The edge **88***c* is brought into contact with the claw **92***a*, and gives rise to the rotation of the rotary pick **92** in the clockwise direction against the elastic force of the cam springs **93**. Subsequently, the claw **92***a*, which is at the opposite position 180 degrees spaced from the claw **92***a* pressed by the edge **88***c*, is brought into contact with the associated reed **83**, and plucks it. The reed **83** vibrates, and generates the tone. When the swingable arm **88** reaches the lower stopper **95**, the reed **83** is vibrating in the space between the claw **92***a* and the next claw **92***a* so that the rotary pick **92** does not interfere with the vibrating reed **83**.

When the magnetic force is removed from the flat coil **86**, the arm spring **89** rotates the swingable arm **88** in the clockwise direction. Although the friction between the claw **92***a* and the swingable arm **88** urges the rotary pick **92** in the counter clockwise direction, the brake unit **93**/**96** does not permit the rotary pick **92** from the reverse rotation. The swingable arm **88** reaches the upper stopper **90**, and the cam springs **93** urge the rotary pick **92** in the clockwise direction so that the next claw **92***a* enters the notch **88***b*.

The musical instrument achieves the advantages by virtue of the solenoid-operated flat actuators FLAT2, rotary picks **92** and brake units **93**/**96**. Moreover, the upper stopper **90** and lower stopper **95** exactly define the upper dead point and lower dead point for the swingable arms **88**. The motion of the swingable arms **88** is constant so that a constant force is exerted on the reeds **83**.

FIGS. **41**A and **41**B show another player's finger **20**O incorporated in a musical instrument according to the present invention. The player's finger **20**O is similar in structure to the player's finger **20I** so that the component parts are labeled with same references designating corresponding parts of the player's finger **20I** without detailed description.

In the musical instrument, plural player's fingers **20**O are disposed in the proximity of the tips of reeds **114**, which radially project from a hub **113***a*. The reeds **114** and hub **113***a* form in combination a daisy reed wheel **113**.

The controller is assumed to energize the solenoid-operated actuator CLY2, current flows through the coil **121**, and magnetic field is created. The pusher **122** is inwardly inclined as indicated by **122(P0)**, and the plunger **126** starts to project upwardly. The pusher **122** is brought into contact with the claw **112***a*, and gives rise to rotation of the rotary pick **112** in the counter clockwise direction. Another claw **112***a* warps the reed **114**, and escape from the reed **144**. Then, the reed **114** vibrates, and generates the tone. The ratchet **115** stops the rotary pick **112**. When the elastic force exceeds the magnetic force, the pusher **122** escapes from the claw **112***a*.

When the pusher **122** reaches the upper dead point **122(P1)**, the controller removes the magnetic field from the solenoid-operated actuator CLY2 so that any magnetic force is not exerted on the pusher **122**. The spring **125** outwardly inclines the pusher **122** as indicated by **122(P2)**, and the plunger **126** is retracted into the bobbin **123***a*. When the plunger **126** reaches the lower dead point, the pusher **122** returns to the rest position **122(P3)**. Thus, the pusher **122** returns to the rest position without any interference with the claw **112***a*.

The player's fingers **20**O achieve all the advantages by virtue of the rotary pick **112**, solenoid-operated actuator CLY2 and the daisy reed wheel **113**. The player's fingers **20I** shown in FIG. **41**B do not set any limit to the positions to be occupied. Other player's fingers may be provided over the rotary picks **112**.

FIGS. **42**A, **42**B and **43** show another musical instrument according to the present invention. The musical instrument largely comprises a tone generator and an automatic player. The tone generator is implemented by a comb-like array of reeds **137**, and the automatic player includes a controller and player's fingers **20**P. The comb-like array **137**, controller and player's fingers **20**P are similar to the comb-like array **137**, controller and player's fingers **20J** shown in FIGS. **27**A, **27**B and **28** so that component parts are labeled with same references designating corresponding parts shown in those figures without detailed description.

Assuming now that the controller energizes the solenoid-operated actuator shown in FIG. **43**A, the current flows through the coil **132**, and creates magnetic field. Then, the plunger **133** frontward projects from the yoke **131**, and the force F2 is transmitted from the plunger **133** through the flexible wire **144** to the pusher **139**. The pusher **139** frontward projects from the guide block **145**, and is brought into contact with one of the claws **140***a*. Although the tip of the pusher **139** is deformed (see FIG. **44**B), the force F2 gives rise to the rotation of the rotary pick **140** over 90 degrees. While the rotary pick **140** is rotating, another claw **140***a* plucks the reed **135** so that the reed **135** vibrates for generating a tone. The claw **140***a*, which has plucked the reed **135**, reaches the position occupied by the claw **140***a* previously pushed by the pusher **139**.

When the controller removes the magnetic field, a return spring (not shown) moves the plunger **133** backwardly, and the plunger **133** is retracted into the yoke **131**. The plunger **133** pulls the flexible wire **144** and the pusher **139**. The pusher **139** slides on the claw **140***a* backwardly. However, the ratchet **142** does not permit the rotary pick **140** to rotate in the counter clockwise direction. The tip of the pusher **139** is warped, and returns to the rest position.

The musical instrument achieves the advantages by virtue of the rotary wheel **140** and rotary pick **140**. Moreover, the solenoid-operated actuators CYL3 are connected to the pushers **139** by means of the flexible wires **144** so that the manufacturer can locate the base plates **130** and **146** at the optimum positions. Thus, the flexible wires **144** enhance the design flexibility.

The yoke **131** may be separated into yokes, which are incorporated in the solenoid-operated actuators CYL3, respectively. The yoke may be replaced with a pair of plates. In this instance, each of the coils **132** is sandwiched between the plates.

The pusher **139** may be replaced with a reciprocating rod **153** and a foldable arm **154** as shown in FIGS. **45**A and **45**B. The reciprocating rod **153** and foldable arm **154** are similar to those shown in FIGS. **30**A and **30**B. Otherwise, a foldable rod **157** may be employed in the player's finger **20**P. The foldable rod **157** is similar to that shown in FIG. **30**C.

As will be understood from the foregoing description, the musical instruments implementing the third embodiment generate the clear tones through the natural vibrations of the reeds. The controllers make the player's fingers pluck the reeds on the basis of the music data so that the automatic players can answer any user's requests. The structures of the musical instruments enhance the design flexibility

The reeds are replaceable with another sort of vibrating members such as, for example, strings or tone bars. Although the strings are plucked, the tone bars are beaten with mallets. In this instance, the player's fingers selective beat the tone bars.

Fourth Embodiment

Prototype

FIGS. **46**, **47**, **48**A and **48**B show another musical instrument embodying the present invention. The musical instrument is categorized in the music box. The musical instrument largely comprises a tone generator and an automatic player as similar to the first, second and third embodiments. The tone generator is implemented by a comb-like array **48**Q of reeds **48***a*, and the automatic player comprises a controller **20**Aq and player's fingers **20**Q. The comb-like array **48**Q of reeds **48***a*, controller **20**Aq and player's fingers **20**Q are similar in structure to the array **48** of reeds **48***a*, controller **20**Ab and player's fingers **20**E shown in FIGS. **16** and **17**. For this reason, component circuits of the controller **20**Aq and component parts of the comb-like array **48**Q and player's fingers **20**Q are labeled with references designating corresponding circuits of the controller **20**Ab and corresponding parts of the array **48** and player's finger **20**E without detailed description.

Assuming now that a user requests the automatic player to perform a piece of music, the central processing unit **11** sequentially accesses music data codes stored in the memory **13**, and instructs the driver circuit **17** to selectively energize the solenoid-operated flat actuators FLAT**1**. While the central processing unit **11** is sequentially processing the music data, the central processing unit **11** is assumed to instruct the driver circuit **17** to pluck the reed **48***a* shown in FIG. **48**A. The flat coil **44** has not been energized so as to keep the swingable arm **43** horizontal. The tip of the blade **45** stands upright, and is spaced from the rotary pick **46**.

The driver circuit **17** determines the pulse width to be required for the target loudness, and the pulse width modulator PWM supplies the driving signal with the pulse width to be required for the target loudness to the flat coil **44**. When the current flows through the flat coil **44**, the magnetic force is exerted on the flat coil **44**, and gives rise to rotation of the swingable arm **43** in the counter clockwise direction. The blade **45** is brought into contact with the flat back surface **46***a***1** of the rotary pick **46**, and pushes it. The rotary pick **46** is driven for rotation over 90 degrees as indicated by arrow AR**5** (see FIG. **49**), and plucks the reed **48***a* with the claw **46** spaced 180 degrees from the claw **46** pushed by the blade **45**. The reed **48***a* vibrates as indicated by arrow AR**6**, and generates the tone. The disk **46***b* is spaced from the vibrating reed **48***a*, and the claws **46***a* are out of the trajectory of the vibrating reed **48***a*. Thus, the rotary pick **46** does not interfere with the vibrating reed **48***a*.

The driver circuit **20**Aq removes the driving signal from the flat coil **44**. Then, the self weight causes the swingable arm **43**, flat coil **44** and blade **45** to return to the rest position shown in FIG. **33**A. The ratchet **53** prevents the rotary pick **46** from the reverse rotation.

In this instance, the controller **20**Aq selectively energizes the flat coils FLAT**1** for plucking the reeds **48***a* with the claws **46***a*. This means that the plural rotary picks **46** can concurrently pluck the reeds **48***a* for producing a chord. The rotary pick **46** is rotated over only the predetermined angle for plucking the reed **48***a*. The rotary pick **46** is responsive to quick repetition so that the automatic player can perform any complicated passage.

The solenoid-operated flat actuators FLAT**1** give rise to the rotation of the associated swingable arms **43** without any physical contact between the flat coils **44** and the yokes **42** and between the arms **43** and the yokes **42**. The arms **43** and flat coils **44** are less worn out. Thus, the player's fingers **20Q** are durable.

The solenoid-operated flat actuators FLAT**1** occupy the space under the reeds **48***a*. In other words, the solenoid-operated flat actuators FLAT**1** are overlapped with the comb-like reed array **48**K. This results in the compact musical instrument.

The automatic player can perform various passages without changing the hardware. The user needs to load a piece of music data into the memory **13**. Thus, the automatic player can answer all the user's requests in so far as the user prepares the pieces of music data.

The solenoid-operated flat actuators FLAT**1** are desirable for the comb-like reed array **48**Q, because the manufacturer can arrange them at small pitches. Even though the reeds **48***a* are extremely narrow, the solenoid-operated flat actuators FLAT**1** are provided in the proximity of the tips of the reeds **48***a*.

The flat coils **44** may be alternated with the yokes **42**. In this instance, the permanent magnet plates **41** are attached to the swingable arms **43**. A large magnet may create a strong magnetic field for all the flat coils **44**.

Modifications

FIGS. **50**A and **50**B show a modification of the player's finger. The player's fingers **20**R are similar to the player's fingers **20**F so that the component parts of the player's finger **20**R are labeled with the component parts of the player's finger **20**F without detailed description.

The guide block **52***a* is formed with a pair of guide groves for upward motion and another pair of guide grooves for downward motion. While the solenoid-operated flat actuator FLAT**1** gives rise to the rotation of the arm **43**, the pin **57** is moved along the pair of guide grooves for the upward motion, and the head portion **51***b* plucks the reed **48***a* for vibrations.

When the pick **51** reaches the upper dead point, the driving signal is removed from the flat coil **44**, and the arm **42** returns to the rest position. The spring **52** makes the pick **51** inclined as indicated by **51(P1)**. The pin **57** enters the pair of guide grooves for the downward motion, and the pin **57** and pair of guide grooves keep the pick **51** inclined. For this reason, the head **51***b* does not interfere with the vibrating reed **48***a*.

The guide block **52***a* and pin **57** keep the trajectory of the pusher **51** stable so that the pusher **51** does not interfere with the vibrating reed **48***a*. The player's finger **20**F has the advantages by virtue of the solenoid-operated flat actuators FLAT**1**.

FIGS. **51**, **52**A, **52**B and **52**C show another musical instrument according to the present invention. The musical instrument largely comprises a tone generator and an automatic player. The tone generator is implemented by a comb-like reed array, and the automatic player includes a controller and player's fingers **20S**. The comb-like reed array, controller and player's fingers **20S** are similar to those of the musical instrument shown in FIGS. **24**, **25**A, **25**B and **25**C. For this reason, the component parts are labeled with same references designating corresponding parts shown in those figures without detailed description.

A pair of cams **96** are fixed to the side surfaces of each rotary pick **92**, and the cam spring **93** is bifurcated so that twp spring leaves are pressed to the cams **96**, respectively.

Assuming now that the controller energizes the flat coil **86** shown in FIG. **52**A, the magnetic force is exerted on the flat coil **86** and, accordingly, the swingable arm **88** so as to give rise to the rotation of the swingable arm **88** about the shaft **87** in the counter clockwise direction against the elastic force of the arm spring **89**. The swingable arm **88** starts the rotation at the rest position **88(P0)**, and is moved on the trajectory toward the lower stopper **95**.

The edge **88***c* is brought into contact with the claw **92***a*, and gives rise to the rotation of the rotary pick **92** in the clockwise direction against the elastic force of the cam springs **93**. Subsequently, the claw **92***a*, which is at the opposite position 180 degrees spaced from the claw **92***a* pressed by the edge **88***c*, is brought into contact with the associated reed **83**, and plucks it. The reed **83** vibrates, and generates the tone. When the swingable arm **88** reaches the lower stopper **95**, the reed **83** is vibrating in the space between the claw **92***a* and the next claw **92***a* so that the rotary pick **92** does not interfere with the vibrating reed **83**.

When the magnetic force is removed from the flat coil **86**, the arm spring **89** rotates the swingable arm **88** in the clockwise direction. Although the friction between the claw **92***a* and the swingable arm **88** urges the rotary pick **92** in the counter clockwise direction, the brake unit **93**/**96** does not permit the rotary pick **92** from the reverse rotation. The swingable arm **88** reaches the upper stopper **90**, and the cam springs **93** urge the rotary pick **92** in the clockwise direction so that the next claw **92***a* enters the notch **88***b*.

The player's finger **20**M plucks the associated reed **61** as shown in FIGS. **38**A to **38**H. FIG. **38**A shows the plunger **71** at the upper dead point, and the claw **66***a***1** is resting in the ring space **70***a*. The controller is assumed to energize the coil **68**. The plunger **70** starts the downward motion against the elastic force of the spring **69**. The inner portion **71***a* is brought into contact with the claw **66***a***1** as shown in FIG. **38**B. However, the claw **66***a***3** is still spaced from the tip of the reed **61**.

The plunger **70** is further moved downwardly, and gives rise to the rotation of the rotary pick **66** in the clockwise direction. The cam plates **76** are rotated against the elastic force of cum springs **75** exerted on the corners, and the claw **66***a***3** plucks the reed **61** as shown in FIG. **38**C. The reed **61** vibrates, and generates a tone. The plunger **70** is further moved downwardly, and the rotary pick **66** is rotated in the clockwise direction. However, the next claw **66***a***2** has not reached the vibrating reed **61**, and the rotary pick **66** does not interfere with the vibrating reed **61** as shown in FIG. **38**D. When the plunger **70** reaches the lower dead point, the next claw **66***a***2** is still spaced from the vibrating reed **61**.

The magnetic field is removed from the solenoid-operated cylindrical actuator CYL**1**, and the plunger spring **69** urges the plunger **70** in the upward direction. Although the head block **71** pushes the claw **66***a***4**, the cam springs **75** and cam plates **76** do not permit the rotary pick **76** to be rotated in the counter clockwise direction, because the braking force is larger than the friction between the head block **71** and the claw **66***a***4** (see FIG. **38**E).

FIGS. **53**F and **53**G illustrate the motion of the rotary pick **92** in detail. FIG. **53**A shows the arm at the rest position. The arm **88** starts to rotate in the counter clockwise direction. The edge **88***c* is brought into contact with the claw **92***a***2** as shown in FIG. **53**B, and pushes the claw **92***a***2** of the rotary pick **92** as shown in FIG. **53**C. The rotary pick **92** is drive for rotation over the predetermined angle against the elastic force of the cam spring **93**, and plucks the reed **83** with the claw **92***a***3**. The reed **83** vibrates for generating the tone. The rotary pick **92** stops the rotation, and the reed **83** freely vibrates the gap between the claws **92***a***3** and **92***a***2** as shown in FIG. **53**D.

The arm **88** starts to return to the upper dead point as indicated by FIG. **53**E. Although the arm **88** slides on the claw **92***a***2**, the cam plates **96** and cam spring **93** do not permit the rotary pick **92** to rotate in the counter clockwise direction, and the rotary pick **92** keeps the attitude unchanged as shown in FIGS. **53**F and **53**G. When the arm **88** reaches the upper stopper **90**, the next claw **92***a***2** is in the space as shown in FIG. **53**H.

As will be understood, the musical instrument has the advantages by virtue of the solenoid-operated flat actuators FLAT**2**. The manufacturer can arrange the reeds at short intervals so that the musical instrument is compact. The arm **88** per se pushes the claws **92***a*, and the cam plates/cam spring **93**/**95** prevent the rotary pick **92** from the reverse rotation. This results in that the reeds **83** are constantly plucked with the claws **92***a*. This means that the loudness is exactly controlled.

The solenoid-operated flat actuators FLAT**2** may linearly move plates in the up-and-down direction. The reeds **83** may be replaced with strings or tone bars. In case where the tone bars are employed in a musical instrument, the player's fingers strike the tone bars with mallets or sticks.

Fifth Embodiment

FIGS. **54** and **55** show another musical instrument embodying the present invention. The musical instrument is categorized in the music box. The musical instrument also largely comprises a tone generator and an automatic player. The tone generator is implemented by a comb-like reed array **3**. The comb-like reed array **3** has a boss portion **3***a* fixed to a block **2**, which in turn is fixed to a base plate **1**. Plural reeds **3***b* project from the boss portion **3***a* in parallel to one another. The reeds **3***b* are designed such that the they generate the tones at intervals of semitone. References **3***b*(d**1**), **3***b*(d**2**), . . . and **3***b*(dn) are individually assigned to the reeds **3***b*. The reed **3***b*(d**1**) generates the tone with the pitch name C, and the reed **3***b*(d**2**) generates the tone with the pitch name C#. Thus, the tones of the scale are respectively assigned to the reeds **3***b*(d**1**) to **3***b*(dn).

The automatic player includes a controller **20**At and plural player's fingers **20**T. An electric motor M is shared among the player's fingers **20**T (see FIG. **56**), and one of the particular features of the musical instrument is directed to the electric motor M, with which the cams and cam springs are replaced. The particular feature will be described in detail in conjunction with the structure of the player's fingers **20**T.

The controller **20**At includes a MIDI interface **21**, a bus system **22**, a random access memory **23**, a read only memory **24**, a central processing unit **25** and a driver circuit **26** as shown in FIG. **57**. The MIDI interface **21**, random access memory **23**, read only memory **24**, central processing unit **25** and driver circuit **26** are connected to the bus system **22** so that digital codes are transferred through the bus system **22** between those system components **21**/**23**/**24**/**25**/**26**.

The random access memory **23** has a capacity large enough to store plural sets of music data codes representative of several pieces of music. Computer programs are stored in the read only memory **24** together with data codes representative of data required for plucking the reeds **3***b*. Other sets of music data codes, with which the automatic player performs pieces of music, may be stored in the read only memory **24**. The automatic player may require several minutes for performing a piece of music represented by a set of music data codes. The music data codes specify the pitch of a tone to be generated, touch and timing at which the tone is to be generated, and are called as "note event data".

The central processing unit **25** is responsive to user's instructions given through a manipulating panel (not shown). When a user specifies a piece of music through the manipulating panel, the central processing unit **25** starts to sequentially execute instruction codes of the computer program, and successively fetches the music data codes stored in the random access memory **23** or read only memory **24** in order to the timing. The central processing unit **25** specifies the player's finger **20**T to be actuated on the basis of the piece of music data representative of the pitch and note-on event. The central processing unit **25** informs the driver circuit **26** of the player's finger **20**T to be actuated at the timing at which the tone is to be generated. Another task to be achieved through the sequential execution of the computer program relates to the MIDI interface **21**, and will be hereinafter described.

The MIDI interface **21** is connected to an external MIDI data source (not shown), and receives data codes of a standard MIDI file, by way of example. A detachable memory device such as, for example, a memory card is also connectable to the MIDI interface **21**, and the data codes are supplied from the detachable memory to the MIDI interface

21. The data codes are transferred through the bus system **22** to the random access memory **23**, and are stored therein. The central processing unit **25** converts the data codes in the standard MIDI file to other data codes in another format for the musical instrument according to the present invention. The central processing unit **25** stores the data codes in the other format in the random access memory **23**, again.

Turning back to FIGS. **54** and **55**, each of the player's fingers **20**T includes a solenoid-operated flat actuator FLAT**4**, a swingable arm **8**, a spring **9** and a rotary pick **6**. Shafts **5**/**7**, a stopper **10** and a base chassis **4** are shared among the player's fingers **20**T. The base chassis **4** is spaced from the block **2**, and is fixed to the base plate **1**. The shaft **5** is rotatably supported by the base chassis **4**, and the other shaft **7** is fixedly supported by the base chassis **4**. The shafts **5** and **7** extend in parallel to one another in a direction parallel to the virtual line on which the tips of the reeds **3***b* are rowed up, and the shaft **5** is closer to the tips of the reeds **3***b* than the other shaft **7**. The solenoid-operated flat actuators FLAT**4** are disposed between the shafts **5** and **7**. The stopper **10** is spaced from the base plate **1** in a direction normal to the upper surface of the base plate **1**, and extends in parallel to the shafts **5** and **7** and over the player's fingers **20**T.

The rotary picks **6** are arranged on the shaft **5** at short intervals, and the electric motor M has an output shaft coupled to one end of the shaft **5** as will be better seen in FIG. **56**. The rotary picks have respective boss portions **6***a*, which are formed with center holes **6***b*, respectively, and claws **6***c*. In this instance, four claws **6***c* project from each boss portion **6***a*, and are 90 degrees spaced from one another. The shaft **5** passes through the center holes **6***b*, and the rotary picks **6** keep themselves spaced from the adjacent rotary picks **6** at the short intervals. However, the rotary picks **6** are never fixed to the shaft **5**. While the electric motor M drives the output shaft for rotation, the shaft **5** is rotated together with the output shaft in a direction indicated by arrow AR**8** (see FIG. **56**), which is corresponding to the clockwise direction in FIG. **55**, and urges the rotary picks **6** to rotate together due to the friction between the output surface of the shaft **5** and the inner surfaces of the boss portions **6***a*. In this instance, the rotary picks **6** and the shaft **5** are made of synthetic resin. However, the rotary picks **6** and shaft **5** may be made of metal or alloy in another musical instrument.

Although the base portion **6***a* is spaced from the tip of the associated reed **3***b*, the claws **6***c* reach the tip of the associated reed **3***b* so that the rotary pick **3** plucks the reed **3***b* with the claws **6***c*. As described hereinlater in detail, the swingable arms **8** give rise to rotation of the associated rotary picks **6** in a direction indicated by arrow AR**9**, and the rotary picks **6** make the tips of the associated reeds **3***b* on the rounded surfaces **6***d* of the claws **6***c*. The individual rotary picks **6** are labeled with **6**(p**1**), **6**(p**2**), . . . and **6**(pn), and the rotary picks **6**(p**1**), **6**(p**2**), . . . and **6**(pn) are respectively associated with the reeds **3***b*(d**1**), **3***b*(d**2**), . . . and **3***b*(dn).

The swingable arms **8** are rotatably supported by the shaft **7** at the short intervals, and the springs **9** always urge the associated swingable arms **8** in the clockwise direction in FIG. **55**. The stopper **10** receives the swingable arms **8**, and defines the upper dead points for the swingable arms **8**. The elastic force exerted on each swingable arm **8** is larger than the force exerted on the swingable arm **8** due to the friction between the outer surface of the shaft **5** and the inner surface of the associated rotary pick **6**. For this reason, even though the shaft **5** is driven for rotation, the springs **9** keep the associated swingable arms **8** at the rest position beneath the stopper **10**.

Each of the swingable arm **8** has a head portion **8***a*, and a notch **8***b* is formed in the head portion **8***a*. The notch **8***b* is so wide that one of the claws **6***c* of the associated rotary pick **6** can enter the notch **8***b*. The individual swingable arms **8** are labeled with **8**(s**1**), **8**(s**2**), . . . and **8**(sn). The swingable arms **8**(s**1**), **8**(s**2**), . . . and **8**(sn) are respectively associated with the rotary picks **6**(p**1**), **6**(p**2**), . . . and **6**(pn) and, accordingly, with the reeds **3***b*(d**1**), **3***d*(b**2**), . . . and **3***b*(dn).

The solenoid-operated flat actuators FLAT**4** include permanent magnet plates **12**, yokes **13** and respective flat coils **11**. The yokes **13** are taller than the permanent magnet plates **12**, and the yokes **13** and permanent magnet plates **12** are alternated with one another. For this reason, a gap takes place between the adjacent two yokes **13**, and the swingable arms **8** are respectively assigned to the gaps. The flat coils **11** are fixed to the side surfaces of the associated swingable arms **8**, and are moved together with the associated swingable arms **8**. The coil **11** is so short that the flat coil **11** is thin enough to be resting in the gap together with the swingable arm without any physical contact with the yokes **13**.

Assuming now that the user requests the automatic player to perform a piece of music, the central processing unit **25** accesses the random access memory **23** or read only memory **24**, and sequentially fetches the music data codes representative of the tones to be generated. The central processing unit **25** specifies the player's fingers **20**T to be actuated, and instructs the driver circuit **26** to energizes the solenoid-operated flat actuators FLAT**4** at the appropriate times. The note-on events are defined on the lapse of time from the initiation of the performance, and the controller **20**At increments the tempo clocks. When the lapse of time reaches the time at which the note-on event is to occur, the central processing unit **25** instructs the driver circuit **26** to supply the driving signal to the player's finger.

While the automatic player is performing the piece of music, the controller **20**At is assumed to energize the solenoid-operated flat actuator FLAT**4** shown in FIG. **55**. Before the controller **20**At energizes the solenoid-operated flat actuator FLAT**4**, the head portion **8***a* was in contact with the stopper **10**, and the claw **6***c***1** was rest in the notch **8***b* as shown in FIG. **58**A. The claw **6***c***1** was held in contact with the lower edge of the head portion **8***a*. Although the shaft **5** was rotating in the center hole **6***b* in the rotary pick **6**, the moment exerted on the head portion **8***a* due to the friction was smaller than the moment due to the elastic force of the string, and the shaft **5** was rotating in the center hole **6***b* of the rotary pick **6**.

When the current flows through the flat coil **11**, the magnetic force is exerted on the flat coil **11**, and the associated swingable arm **8** starts the rotation as indicated by arrow x against the elastic force of the spring **9**. The head portion **8***a* is spaced from the stopper **10**, and the edge **8***c* is brought into contact with the claw **6***c***1**. The head portion **8***a* pushes the claw **6***c***1** downwardly, and gives rise to the rotation of the rotary pick **6** in the clockwise direction against the friction between the outer surface of the shaft **5** and the inner surface of the boss portion **6***a*. The claw **6***c***3** is brought into contact with the tip of the associated reed **3***b*, and makes the tip slide on the rounded surface **6***d*. When the claw **6***c***3** escapes from the tip of the reed **3***b*, the reed **3***b* vibrates for generating the tone as shown in FIG. **58**B. The reed **3***b* is vibrating in the gap between the claw **6***c***3** and the next claw **6***c***2** so that the rotary pick **6** does not interfere with the vibrating reed **3***b*.

When the head portion **8***a* reaches the lower dead point, the controller **20**At removes the magnetic force from the flat coil **11**, and the head portion **8***a* starts to return toward the rest position. Although the front end surface of the head portion **8***a* slides on the rotary pick **6**, the rotating shaft **5** urges the rotary pick **6** in the clockwise direction so that the rotary pick **6** keeps the attitude thereof unchanged as shown in FIG. **58**C.

When the head portion **8***a* reaches the rest position, the shaft **5** slightly rotates the rotary pick **6**, and the next claw **6***c***4** enters the notch **8***b*.

As will be understood from the foregoing description, the musical instrument has the advantages by virtue of the solenoid-operated flat coils FLAT**4**. The rotary picks **6** are urged by the rotating shaft **5**, and neither ratchet nor combination of cams and cam springs are required for the rotary picks **6**. This results in the simple structure of the player's fingers **20**T.

The player's fingers **20**T may be replaced with player's fingers **20**U. In the player's finger **20**U, the solenoid-operated flat actuator FLAT and swingable arm **8** are replaced with a solenoid-operated cylindrical actuator CYL**6** and a plunger head **24***a* as shown in FIG. **59**. The solenoid-operated cylindrical actuator CYL**6** includes yoke plates **23***a* spaced from each other in an up-and-down direction, a cylindrical coil **22** sandwiched between the yoke plates **23***a* and **23***b*, a plunger **24** projectable from and retractable into the space defined by the cylindrical coil **22** and a spring **25** urging the plunger **24** upwardly. The plunger head **24***a* is connected to the upper end of the plunger **24**, and a ring space **24***b* takes place between the plunger **24** and the plunger head **24***a*. The spring **26** urges the plunger upwardly so that the plunger head **24***a* is held in contact with the stopper **10** in the absence of the magnetic field, and the friction between the outer surface of the shaft **5** and the inner surface of the rotary pick **6** causes the claw **6***c* to be in contact with the upper edge of the plunger **24**.

Assuming now that the controller energizes the solenoid operated cylindrical actuator CYL**6**, the plunger **24** is moved downwardly as indicated by x, and the plunger head **24***a* is brought into contact with the claw **6***c*. The plunger head **24***a* pushes down the claw **6***c*, and gives rise to rotation of the rotary pick **6** in the clockwise direction. Another claw **6***c* plucks the reed **3***b* so that the reed **3***b* vibrates for generating the tone.

When the plunger **24** reaches the lower dead point, the controller removes the magnetic field from the solenoid-operated cylindrical actuator CYL**6**, and the spring **25** makes the plunger **24** project upwardly. Since the rotating shaft **5** exerts the moment on the rotary pick **6**, the rotary pick **6** is never rotated in the counter clockwise direction. Thus, the rotary pick **6** permits the reed **3***b* to freely vibrate in the gap between the claws **6***c*. When the plunger head **24***a* is brought into contact with the stopper **10**, the next claw **6***c* enters the ring space for the next plucking.

The solenoid-operated cylindrical actuators CLY**6** may be arranged in two or three stages stacked with one another for preventing the coils **21** from interference. In this instance, the plunger heads **24***a* are thinned so that the player's fingers are arranged like the player's fingers **20**T.

The solenoid-operated cylindrical actuators CYL**6** may be arranged in parallel to the base plate **1**. In this instance, the plungers **24** and plunger heads **24***a* horizontally project from and are retracted into the yokes for driving the rotary picks **6** for rotation.

The electric motor M may intermittently rotate the shaft **5** for keeping the rotary picks **6** stable during the plunger's motion from the lower dead points to the upper dead points.

The solenoid-operated cylindrical actuators CYL**6** may rotate the associated rotary picks **6** during the straight motion from the lower dead points to the upper dead points. The shaft **5** prevents the rotary picks **6** from the reverse rotation in the straight motion from the upper head points to the lower head points. The plucking with the swingable arms **8** are similarly changed from the counter clockwise direction to the clockwise direction.

The rotary picks **6** may be driven for rotation by the shaft **5** so as to pluck the reeds **3***b*. In this instance, the swingable arms **8** stop the rotation of the rotary picks **6** while the reeds **3***b* are to be silent.

Although particular embodiments of the present invention have been shown and described, it will be apparent to those skilled in the art that various changes and modifications may be made without departing from the spirit and scope of the present invention.

For example, the boss portion **33***a* may have a circular periphery. In this instance, the tips **33***c* are arranged on a certain curved line such as an involute line.

The resonator box **43** or both of the resonator box **43** and bell **45** may be attached to one of the music boxes shown in FIGS. **1** to **6**D.

In a multiple music box according to the present invention, all the daisy reed wheels **32** may be assigned a register. The performing boxes **41**/**141** may play only one part of a piece of music. In this instance, the tones are richer than those of the other music boxes.

The tone generator and automatic player may form parts of a toy, electrical goods or a new sort of musical instrument. The automatic players described hereinbefore may be provided for a harp or another plucking instrument. Tone bars may be used for a musical instrument according to the present invention. In this instance, the automatic player does not pluck the tone bars, but strikes the tone bars.

The music data codes may be supplied from a musical instrument, on which a human player plays a piece of music, to the controller in real time fashion. In this instance, the musical instrument according to the present invention performs a part of the piece of music in ensemble with the other musical instrument.

In the modification shown in FIGS. **17** to **19**, the solenoid-operated flat actuators FLAT**1** may occupy the space over the array **48** of reeds or space in front of the array **48** of reeds. Thus, the manufacturer freely designs the musical instrument. The permanent magnet plates **41** may be fixed to the swingable arms **43**. In this instance, the flat coils **44** are placed between the yokes **42**. Namely, the permanent magnet plates **41** and flat coils **44** are exchangeable. Moreover, plural swingable arms **43** may be assigned to one of the gap between the yokes **43**. In this instance, the permanent magnet plates **41** or flat coils **44** are expected to create strong magnetic field in the gap.

Although the solenoid-operated flat actuators FLAT**1**/FLAT**2** give rise to rotations of the swingable arms **43**/**88** in the musical instruments, other solenoid-operated flat actuators may move plates linearly.

What is claimed is:

1. A musical instrument comprising:

a tone generator having vibratory members radially arranged with respect to a center of said tone generator; and

an automatic player selectively generating vibrations of said vibratory members for producing tones different in pitch from one another through said vibrations, and including:

player's fingers arranged in the proximity of outer ends of said vibratory members and responsive to an instruction so as to convert energy to said vibrations of said vibratory members, and

a controller giving said instruction selectively to said player's fingers so as to make the player's fingers start to convert said energy to said vibrations of the associated vibratory members on the basis of pieces of music data that are changeable without changing a physical structure of said controller.

2. The musical instrument as set forth in claim **1**, in which said controller concurrently activates more than one player's finger for generating the tones.

3. The musical instrument as set forth in claim **1**, in which each of said player's fingers includes

a pick for plucking associated one of said vibratory members,

an actuator connected to said controller so as to be energized by said controller for plucking said associated one of said vibratory members with said pick and

an attitude controller connected to said pick and changing said pick between a plucking attitude for plucking said associated one of said vibratory members and a shunt position for passing beside said associated one of said vibratory members without any interference with said vibrations.

4. The musical instrument as set forth in claim **3**, in which said attitude controller includes an offset yoke of a solenoid-operated actuator serving as said actuator so that said pick is inclined toward said associated one of said vibratory members while a plunger of said solenoid-operated actuator is moving said pick to said associated one of said vibratory members for plucking, said attitude controller further includes an elastic member connected to said pick so that said pick is oppositely inclined while said plunger is making said pick spaced from the vibrating vibratory member.

5. The musical instrument as set forth in claim **1**, in which said vibratory members are reeds.

6. The musical instrument as set forth in claim **1**, in which said vibratory members are strings.

7. The musical instrument as set forth in claim **1**, in which said tone generator and said player's fingers form a playing unit, and more than one playing unit is combined together for producing the tones under the control of said controller.

8. The musical instrument as set forth in claim **7**, further comprising a resonator connected to said more than one playing unit for enlarging the loudness of said tones.

9. The musical instrument as set forth in claim **1**, further comprising holders each having a portion at which one of said vibratory members is fixed and a space where one of said player's fingers is accommodated for generating said one of said vibratory members.

10. The musical instrument as set forth in claim **3**, each of said player's fingers further includes a guide for spacing said pick from associated one of said vibratory members after generating said vibrations therein.

11. The musical instrument as set forth in claim **10**, in which said guide has a pin fixed to said pick and a guide block formed with a first passage for guiding said pin during a first motion of said pick for generating said vibrations and a second passage for guiding said pin during a second motion of said pick for returning to a rest position.

12. The musical instrument as set forth in claim **3**, in which said pick has a boss rotatably supported by a member stationary with respect to said actuator and claws radially projecting from said boss at intervals, and in which said actuator gives rise to rotation over a predetermined angle for plucking said associated one of said vibratory members with one of said claws.

13. The musical instrument as set forth in claim **1**, further comprising a housing accommodating said tone generator and said automatic player so that said tone generator, said automatic player and said housing form in combination a music box.

14. A musical instrument comprising:

a tone generator having an array of vibratory members for generating tones different in pitch from one another through vibrations; and

an automatic player including:

player's fingers responsive to an instruction so as to convert energy to said vibrations of said vibratory members, and

a controller giving said instruction selectively to said player's fingers so as to make the player's fingers start to convert said energy to said vibrations of the associated vibratory members on the basis of pieces of music data that are changeable without changing a physical structure of said controller,

each of said player's fingers having a rotary vibration generator rotatably supported by a stationary member in the proximity of associated one of said vibratory members for generating said vibrations through rotation thereof and an actuator connected to said controller and selectively energized by said controller for rotating said rotary vibration generator.

15. The musical instrument as set forth in claim **14**, in which said controller concurrently activates more than one player's finger for generating the tones.

16. The musical instrument as set forth in claim **14**, in which said rotary vibration generator has a boss portion rotatably supported by said stationary member and plural claws radially projecting from said boss at intervals.

17. The musical instrument as set forth in claim **16**, in which said vibratory members project from a boss portion of said array in parallel to one another, and said rotary vibration generators are respectively provided in the proximity of tips of said vibratory members.

18. The musical instrument as set forth in claim **17**, in which the actuators and said array of vibratory members are overlapped with one another, and said actuators selectively rotate the associated rotary vibration generators over a predetermined angle for plucking said tips of said vibratory members under the control of said controller.

19. The musical instrument as set forth in claim **16**, in which said actuators have array of magnetic plates and yokes alternated with one another for forming gaps between said yokes, respective arms having first end portions rotatably connected to a stationary member, respective flat coils respectively attached to said arms and connected in parallel to said controller, and respective blades connected at second ends of said arm opposite to said first ends and projecting toward said rotary vibration generators for selectively pushing said claws while said arms are rotating about said stationary member.

20. The musical instrument as set forth in claim **15**, in which said actuator includes a movable member for rotating said rotary vibration generator, a flexible wire connected at one end thereof to said movable member and a power generating unit connected to the other end of said flexible wire for exerting a force on said movable member through said flexible wire.

21. The musical instrument as set forth in claim **14**, in which said array of vibratory members is formed in a daisy reed wheel having vibratory reeds radially projecting from a boss portion, and said player's fingers are arranged outside of said daisy reed wheel.

22. The musical instrument as set forth in claim **21**, in which said rotary vibration generator has a boss portion and plural claws radially projecting from said boss portion at intervals, and the rotary vibration generators are provided around said daisy reed wheel for plucking said reeds with the claws.

23. The musical instrument as set forth in claim **14**, further comprising a housing accommodating said tone generator and said automatic player so that said tone generator, said automatic player and said housing form in combination a music box.

24. The musical instrument as set forth in claim **14**, in which said each of said player's fingers further has a back stop so as to permit said rotary vibration generator to unidirectionally rotate.

25. The musical instrument as set forth in claim **24**, in which said back stop is formed by a ratchet.

26. The musical instrument as set forth in claim **24**, in which said back stop is formed by a cam plate fixed to said rotary vibration generator and a cam spring pressed to said cam.

27. The musical instrument as set forth in claim **24**, in which said back stop includes a shaft loosely passing through the rotary vibration generators and a motor connected to said shaft and unidirectionally rotating for urging said vibration generators.

28. A musical instrument comprising:

a tone generator having an array of vibratory members for generating tones different in pitch from one another through vibrations; and

an automatic player including player's fingers for selectively generating said vibrations in said vibratory members and a controller connected to said player's fingers for selectively actuating said player's fingers on the basis of pieces of music data variable without changing a physical structure of said controller,

each of said player's fingers including

a vibration generator moved from a rest position along a first path for generating said vibrations in associated one of said vibratory members and a second path for returning to said rest position,

an actuator connected to said controller and moving said vibration generator along said first path and said second path, and

a route changer connected to said vibration generator for guiding said vibration generator to said second path after generating said vibrations so as to permit the associated vibratory member to freely vibrate without any interference due to said vibration generator passing beside said associated vibratory member along said second path.

29. The musical instrument as set forth in claim **28**, in which said route changer includes a magnetic field generator for forcing said vibration generator to said first path and an elastic member for forcing said vibration generator to said second path.

30. The musical instrument as set forth in claim **29**, in which said magnetic field generator exerts a magnetic force larger than an elastic force of said elastic member on said vibration generator from a rest position to a certain position in said first path, and makes said magnetic force smaller than said elastic force after the generation of said vibration in said first path.

31. The musical instrument as set forth in claim **28**, in which said route changer further includes a guide block having a hollow space partially serving as said first path and partially serving as said second path.

32. The musical instrument as set forth in claim **31**, in which said route changer further includes a guide pin fixed to said vibration generator, and said guide block is formed with a first groove slidably receiving said guide pin for guiding said vibration generator along said first path and a second groove slidably receiving said guide pin for guiding said vibration generator along said second path.

33. The musical instrument as set forth in claim **32**, in which said first groove is connected to a certain portion of said second groove, and said second groove is connected to another certain portion of said first groove, said certain portion and said another certain portion respectively preventing said vibration generator from entering into said first path and said second path so that said vibration generator is moved along said first path, enters said second path over said certain portion, moved along said second path and enters said first path over said another certain portion.

34. The musical instrument as set forth in claim **28**, in which said route changer includes a rotatable disc, and said vibration generator includes claws radially projecting from said rotatable disc at intervals, said rotatable disc causes one of said claws to enter said first path through a rotation over a certain angle and said second path through a further rotation over another certain angle.

35. A musical instrument comprising:

a tone generator having vibratory members radially arranged with respect to a center of said tone generator; and

an automatic player selectively generating vibrations of said vibratory members for producing tones different in pitch from one another through said vibrations, said automatic player comprising:

player's fingers arranged in the proximity of outer ends of said vibratory members and respectively associated with said vibratory members, and

a controller connected to said player's fingers for selectively and electrically actuating said player's fingers on the basis of pieces of music data that are changeable without changing a physical structure of said controller.

36. A musical instrument comprising:

a tone generator having an array of vibratory members for generating tones different in pitch from one another through vibrations; and

an automatic player comprising:

player's fingers respectively associated with said vibratory members for selectively generating said vibrations in said vibratory members, and

a controller connected to said player's fingers for selectively and electrically actuating said player's fingers on the basis of pieces of music data that are changeable without changing a physical structure of said controller,

each of said player's fingers having a rotary vibration generator rotatably supported by a stationary member in the proximity of associated one of said vibratory members for generating said vibrations through rotation thereof and an actuator connected to said controller and selectively and electrically energized by said controller for rotating said rotary vibration generator.

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